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ORIGINAL ARTICLES

ROOTSTOCK TRIALS IN THE PUNJAB

IV. THE INFLUENCE OF DIFFERENT ROOTSTOCKS ON THE VIGOUR AND CROPPING OF MALTA ORANGE

By SHAM SINGH,* Assistant Agricultural Commissioner with the Government of India, New Delhi and R. L. NAGPAL,** Horticulturist to the Government of Bombay, Poona

(Received for publication on 11 December 1953)

(With eight text-figures)

THE Malta orange develops rich colour and attains superb quality in Northern India where, during the season of maturity, the weather is cool and dry for well over four months beginning from the middle of October. Its cultivation in the Punjab became most popular in the canal colonies, where extensive areas with adequate supplies of canal water were available for the purpose. Even under those conditions, the Government had to make a special arrangement for assuring adequate water supplies to help establishing citrus orchards. The Agricultural Department in the Punjab had also a well-equipped Fruit Section with qualified and experienced personnel to help prospective fruit growers in every respect. And this paved the way for a phenomenal increase in the fruit acreage of the province in a short period, particularly in respect of Malta orange.

The acreage under fruit trees in the undivided Punjab was of the order of one lac of acres of which nearly 40,000 acres were estimated under Malta orange alone. This shows that Malta orange attracted better attention of the growers than other fruits and the cause of this popularity may be due to various reasons connected with its easy cultivation and marketing. The most prized variety was and continues to be the Blood Red. According to Bonavia [1880] the Blood Red variety was first introduced in the Punjab at Gujranwala between 1852-56 by Col. Clarke. Several other varieties of Malta orange were also introduced through the individual efforts of some of the elite growers, the prominent among whom were Dr G. S. Cheema† of Fruit Farm, Montgomery, late Captain R. Mitchel of Renala Khurd, Montgomery and late S. Nahar Singh of Bishanpura, P. O. Duraha, District Ludhiana.

The Government action to explore the possibilities of this fruit in the Punjab began in right earnest when Mr. D. Milne—the then Economic Botanist, Punjab—

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* *Formerly* Assistant Horticulturist, In-charge Horticultural Research Sub-Station, Montgomery.

** *Formerly* Research Assistant at the Horticultural Research Sub-Station, Montgomery.

† Dr G. S. Cheema retired as Fruit Development Adviser to the Government of India in 1949.

introduced about half a dozen varieties of Malta orange from the Botanical Gardens, Saharanpur. Later in 1921, the Government offered land on lease for the trial of Malta orange on a commercial scale. Two such plantations, one at Renala Khurd and the other at Montgomery, in the Montgomery district, were established. The introduction and trial of Malta varieties was further intensified by the Fruit Specialist, Punjab, by importing important Malta varieties grown all over the world. As a result of this work, two varieties—one called Valencia Late which was imported from the U. S. A. and the other named Pineapple introduced from South Africa—came into prominence. The earliest introductions namely, Malta Local and Blood Red, which established themselves in the province before the new importations came to the fore, were included in the rootstock trials, initiated at Montgomery in 1937.

In the first two articles in this series [Lal Singh and Sham Singh, 1942 and 1944] the influence of different rootstocks on tree vigour alone was reported. Since then, the data in respect of both tree vigour and cropping of all the four scions under trial were collected and compiled. Such data in the case of Marsh Seedless grapefruit had already been published [Sham Singh and Nagpal 1947]. The present communication deals with similar information in respect of two scions, viz. Malta Local and Blood Red. The data cover the period of the first four years of fruit bearing in case of both the varieties (1941-1944).

Material and layout

For details regarding the preparation of material and layout, the reader is referred to a previous communication in this series by Lal Singh and Sham Singh [1942]. The various scion-stock combinations here under study are set out in Table I.

Table I

The different scion-stock combinations under trial

Field No.	Method of raising the root-stock	Name of scion-stock combination	No. of trees under study	English equivalents of root stock	Specific names
5	Seed	Malta local on *kharna khatta*	24	-*nil*-	*C. karna* Raf.
5	Seed	Malta local on *jatti khatti*	24	Rough lemon	*C. limonia* Osbeck
5	Seed	Malta local on *nasnaran*	24	-*nil*-	*C.* species
5	Seed	Malta local on *mitha*	24	Sweet lime	*C. aurantifolia* Var. Swingle
5	Seed	Malta local on *mokari*	24	Citron	*C. medica* Linn.
10	Cutting	Malta local on *kharna khatta*	18	-*nil*-	*C. karna* Raf.
10	Cutting	Malta local on *jatti khatti*	18	Rough lemon	*C. limonia* Osbeck
10	Cutting	Malta local on *mitha*	18	Sweet lime	*C. aurantifolia* Var. Swingle
10	Cutting	Malta local on *mokari*	18	Citron	*C. medica* Linn.

TABLE I—(*contd.*)

The different scion-stock combinations under trial

Field No.	Method of raising the root stock	Name of Scion stock combination	No. of trees under study	English equivalents of rootstock	Specific names
3	Seed	Malta Blood Red on *kharna khatta*	18	*-nil-*	*C. karna* Raf.
3	Seed	Malta Blood Red on *jatti khatti*	18	Rough lemon	*C. limonia* Osbeck
3	Seed	Malta Blood Red on *mitha*	18	Sweet lime	*C. aurantifolia* Var. Swingle
3	Seed	Malta Blood Red on *mokari*	18	Citron	*C. medica* Linn.
11	Cutting	Malta Blood Red on *kharna khatta*	18	*-nil-*	*C. karna* Raf.
11	Cutting	Malta Blood Red on *jatti khatti*	18	Rough lemon	*C. limonia* Osbeck
11	Cutting	Malta Blood Red on *mitha*	18	Sweet lime	*C. aurantifolia* Var. Swingle
11	Cutting	Malta Blood Red on *Jullundari khatti*	18	Smooth lemon	*C. limonia*

The data in Table I show that the experimental material constituted two sets. In the first set, the two varieties of Malta orange were budded on apogamic seedlings of rootstock species whereas, in the second set, the same two varieties were budded on vegetatively propagated rootstock material (propagated by stem cuttings). The two scion varieties growing on rootstocks propagated in two different ways constitute the four sets of experimental material, planted in four different fields, and are, therefore, treated as four independent and self-contained field trials. The results of these trials are embodied in the present communication with a view to study the performance of Malta Local and Blood Red varieties on rootstocks raised from seeds (apogamic seedlings) and cuttings (vegetatively propagated).

Data collected

Data regarding the annual stem girth of individual trees under experiment and their fruit yield were collected in the manner described in a previous communication in this series by Sham Singh and Nagpal, [1947].

PRESENTATION AND DISCUSSION OF RESULTS

The data in respect of vigour (indicated by stem girth measurements) and cropping (indicated by the number of fruits borne per tree) of both the scion varieties namely, Malta Local and Blood Red as influenced by different rootstocks in all the four field trials are discussed in this paper. In the interest of clarity, however, the data in respect of the two scion varieties have been presented and discussed separately.

TABLE II

*Tree-size and cumulative cropping of Malta Local * trees on certain rootstocks propagated from seeds*

Year of observation	Growing season	Rootstocks										S. E.		C. D. for P=·05	
		Kharna khatta		Rough lemon		*Nasnaran*		Sweet lime		Citron					
		Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield
1940	1939	17·6	..	15·5	..	15·7	..	13·9	..	13·6	..	0·59	..	1·7	..
1941	1940	25·5	9	23·4	..	23·9	8	19·1	3	18·0	4	0·63	1·57	1·9	5
1942	1941	32·9	52	31·2	15	32·5	9	25·1	26	21·6	27	0·91	4·28	2·7	13
1943	1942	39·2	140	37·7	63	40·0	78	28·0	32	24·6	42	1·12	16·98	3·3	50
1944	1943	44·4	349	43·1	203	46·5	237	30·8	97	26·9	92	1·45	34·24	4·3	101

* Planted in January, 1937

TABLE III

Tree-size and cumulative cropping of Malta Local † trees on certain rootstocks propagated from cuttings

Year of observation	Growing season	Rootstock								S. E.		C. D. for P=·05	
		Kharna khatta		Rough lemon		Sweet lime		Citron					
		Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield
1940	1939	19·1	..	19·2	..	16·4	..	12·9	..	0·58	..	1·8	..
1941	1940	27·3	15	27·5	10	21·9	7	16·4	22	0·80	4·3	2·4	14
1942	1941	34·9	87	35·9	56	27·9	42	20·4	50	1·14	8·42	3·4	25
1943	1942	41·5	180	43·5	119	33·6	56	23·0	75	1·49	19·55	4·5	59
1944	1943	46·4	416	49·5	368	37·2	210	24·1	141	1·73	40·08	5·2	121

† Planted in January, 1937

Malta Local Scion

The data regarding tree-size and cropping of Malta Local trees (cumulative yield as represented by the number of fruits borne per tree from the time the trees commenced fruiting till the year of observation) on apogamic seedling rootstocks and vegetatively propagated rootstocks are set out in Tables II and III respectively.

It is clear from the data in Tables II and III that no crop was harvested from the trees for the first four years (1937-1940). This gave the trees in both the field experiments sufficient time to build up mechanically strong frame-work. The first crop, picked in 1941, was a light one in each case, but more so in case of trees growing on rootstocks propagated from seed. This point is significant as it reveals the precocity of trees growing on rootstocks raised from cuttings which, with the exception of citron, also developed better size during the period of vegetative phase than those on rootstocks raised from seed. To form an idea of the comparative tree-size and cropping of Malta Local trees on both sets of rootstocks, the data in Tables II and III are amalgamated in Table IV.

TABLE IV

The comparative tree-size and cropping of Malta Local trees growing on certain rootstocks raised both from seeds and cuttings

Rootstock under trial	Method of raising the rootstock	1941		1942		1943		1944	
		Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield
Kharna khatta	Seeds	25·5	9	32·9	52	39·2	140	44·4	349
	Cuttings	27·3	15	34·9	87	41·5	180	46·4	416
Rough lemon	Seeds	23·4	0	31·2	15	37·7	63	43·1	203
	Cuttings	27·5	10	35·9	56	43·5	119	49·5	368
Sweet lime	Seeds	19·1	3	25·1	26	28·0	32	30·8	97
	Cuttings	21·9	7	27·9	42	33·6	56	37·2	210
Citron	Seeds	18·0	4	21·6	27	24·6	42	26·9	92
	Cuttings	16·4	22	20·4	50	23·0	75	24·1	141

The data for yield for the year 1941 show that Malta Local trees on vegetatively propagated rootstocks out-yielded those on apogamic seedling rootstocks. This initial advantage in favour of vegetatively propagated rootstocks persisted for the entire period of the first four years of cropping irrespective of the kind of rootstock used. As regards tree-size, the vegetatively propagated rootstocks except citron also induced better size of Malta Local scion. The initial advantage of tree-size also persisted for the first four years of cropping. It is significant, therefore, that Malta Local trees on vegetatively propagated rootstocks not only yielded higher than those on apogamic seedling rootstocks during the first year of cropping but also maintained this performance consistently over the entire period of four

years. It is probable that this order of superiority might continue for some years more. To throw further light on this aspect, the data in Tables II and III are plotted and shown in Fig. 1 and 2. In Figs. 1, the size and cropping of Malta Local trees from year to year on apogamic seedling stocks have been plotted whereas in Fig. 2, the same data in respect of vegetatively propagated rootstocks have been shown.

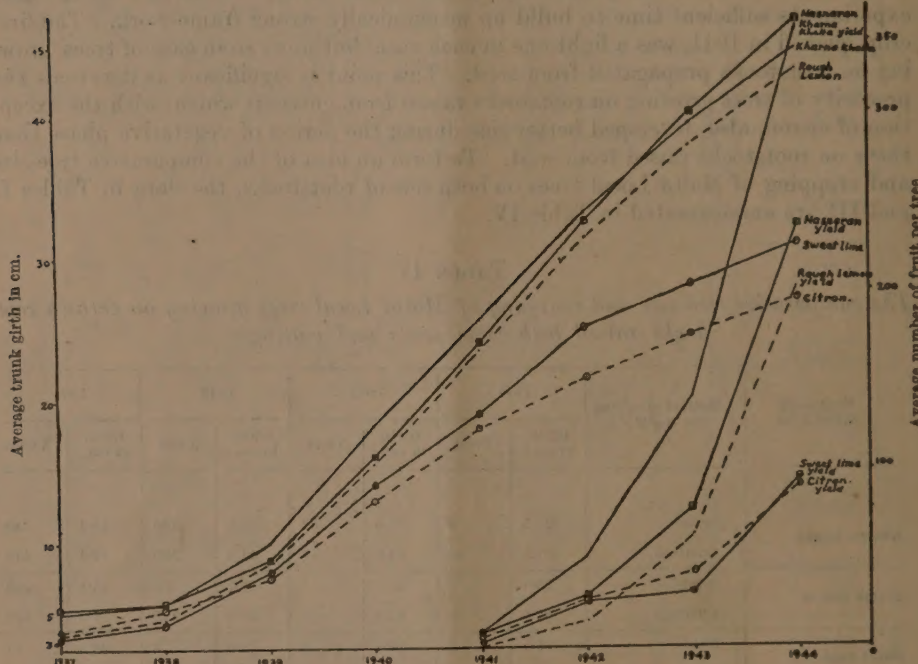

FIG. 1. Tree-size and cropping of Malta Local scion on seedling rootstocks

It would be noticed from Fig. 1 that, by 1941, when the first crop was taken the size of Malta Local trees on rootstocks *kharna khatta*, *nasnaran* and rough lemon, as a group, was considerably bigger than that on the remaining two rootstocks, viz., sweet lime and citron. Within the vigorous group, the trees on *kharna khatta* were significantly more vigorous than those on *nasnaran* and rough lemon. By the end of 1944, the divergence in the curves for tree-size between these two categories of rootstocks was further enlarged, but the differences within the two categories got evened up. The trends, however, were maintained in each case except in case of *kharna khatta* rootstock on which the scion growth got gradually slowed down as compared with other stocks associated with vigorous growing trees and, by 1943, it was overtaken by the trees on *nasnaran*. In considering the tree-size and cropping together, it would be noticed that *kharna khatta* gave the most outstanding

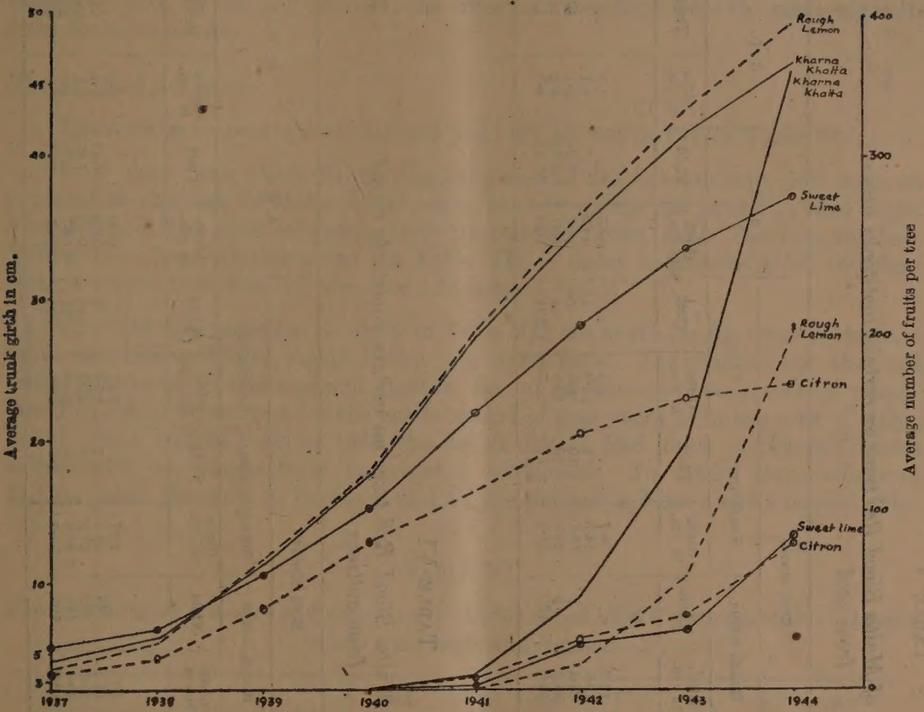

FIG. 2. Tree-size and cropping of Malta Local scion on cutting root stocks

performance in so far as the cropping was concerned, having taken the lead from the first year of fruit bearing. This might explain the comparatively depressed performance of this rootstock with regard to tree-size in later years. There appeared to be little difference in cropping for the remaining three rootstocks during the year 1941 and 1942 but, by 1943, the cropping for *nasnaran* and rough lemon rootstocks was considerably improved though not significantly greater than that for sweet lime and citron rootstocks. The yield differences between these two groups were further intensified by 1944 showing a significantly better yield performance of trees on *nasnaran* and rough lemon than that on sweet lime and citron. It has, therefore, been clearly demonstrated that citron and sweet lime were far inferior to other rootstocks under trial here.

In Fig. 2, the performance of Malta trees on vegetatively raised rootstocks is presented. The results are identical to those shown in Fig. 1 except that the trees on rough lemon which were more or less of the same size as those on *kharna khatta* till 1941, became much bigger in size than those on *kharna khatta* because of the less vegetative growth on *kharna khatta* rootstock consequent upon their outstanding performance in respect of yield. The difference between the size of Malta Local

TABLE V

Tree-size and cumulative cropping of Malta Blood Red trees on certain rootstocks raised from seed

Year of observation	Growing season	Root stocks								S. E.		C. D.	
		Kharna khatta		Rough lemon		Sweet lime		Citron					
		Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield
1940	1939	10·1	..	12·9	..	9·7	..	9·5	..	0·55	..	1·7	..
1941	1940	14·8	..	19·5	..	14·5	2	12·9	1	0·69	..	2·1	..
1942	1941	19·1	11	27·1	3	19·1	10	16·5	6	1·01	3·34	3·1	10
1943	1942	22·8	38	34·9	9	23·3	20	19·9	19	1·41	4·79	4·2	14
1944	1943	26·1	164	42·0	170	27·3	59	22·7	104	1·90	13·44	5·7	41

TABLE VI

Tree-size and cumulative yield of Malta Blood Red trees on certain rootstocks raised from cuttings

Year of observation	Growing season	Root stocks								S. E.		C. D.	
		Kharna khatta		Rough lemon		Smooth lemon		Sweet lime					
		Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield
1940	1939	14·6	..	16·1	..	10·7	..	12·1	..	0·30	..	0·9	..
1941	1940	17·3	8	23·8	25	16·8	1	16·7	9	0·48	4·15	1·4	12
1942	1941	20·1	55	31·6	72	23·1	4	21·5	16	0·70	7·83	2·1	24
1943	1942	22·9	89	38·4	148	29·6	33	25·6	24	0·67	6·78	2·0	20
1944	1943	24·4	218	42·9	500	34·6	217	28·6	123	0·63	16·1	1·9	49

trees on sweet lime and citron, which was quite considerable by 1941, got further magnified and, by the end of 1944, the trees on sweet lime were far more vigorous than those on citron.

Malta Blood Red scion

The data in respect of tree-size and yield are set out in Tables V and VI.

It is clear from these Tables that the results are substantially the same as reported in the case of Malta Local scion, thus revealing the precocity and larger size of Blood Red trees on vegetatively propagated rootstocks. The data in these Tables have been amalgamated in Table VII in order to present a full and clear picture of the comparative tree size and annual yields.

The data for comparative study in Table VII are available for three rootstocks only, viz. *kharna khatta*, rough lemon and sweet lime. The results show that the initial advantage of tree-size and yield in favour of trees on vegetatively propagated rootstocks persisted for the entire period of four years as in the case of Malta Local scion except that, by 1944, the size of Blood Red trees on *kharna khatta* deteriorated on vegetatively propagated rootstocks. To study these effects in further detail, the data in Tables V and VI are plotted in Figs. 3 and 4 respectively.

Table VII

The comparative tree-size and cropping of Malta Blood Red trees on certain rootstocks raised from seeds and cuttings

Rootstocks under trial	Method of raising the rootstock	1941		1942		1943		1944	
		Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield
Kharna Khatta	Seeds	14·8	..	19·1	11	22·8	38	26·1	164
	Cuttings	17·3	8	20·1	55	22·9	89	24·4	218
Rough lemon	Seeds	19·5	..	27·1	3	34·9	9	42·0	170
	Cuttings	23·8	25	31·6	72	38·4	148	42·9	500
Sweet lime	Seeds	14·5	2	19·1	10	23·3	20	27·3	59
	Cuttings	16·7	9	21·5	16	25·6	24	28·6	123

It would be noticed from Fig. 3 that the divergence between rough lemon and other rootstocks in respect of tree-size continued to increase from year to year. Among the other rootstocks, Blood Red trees on citron roots failed to grow as fast as those on *kharna khatta* and sweet lime. The fruit borne by Blood Red trees on various rootstocks was very little till 1943 and, by 1944, when the crop was quite

substantial, the trees on rough lemon, which gave the best crop in that year, out-yielded the rest. The behaviour of citron rootstock with Blood Red scion is a little

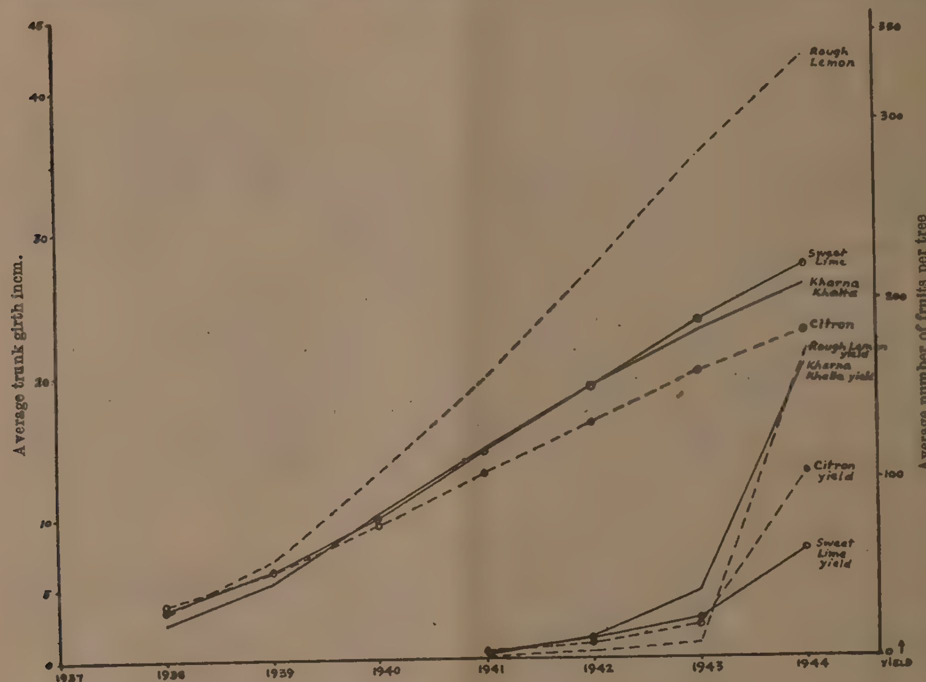

FIG. 3. Tree-size and cropping of Malta Blood Red on seedling root stock

different from that with Malta Local variety in-as-much as the trees on it out-yielded those on sweet lime rootstock.

In Fig. 4, the performance of Blood Red scion on vegetatively propagated rootstocks is shown. It would be seen that rough lemon gave an outstanding performance. It not only produced trees of the largest size but also induced the heaviest yield. The performance of *kharna khatta* which was outstanding in the pre-bearing age, had considerably deteriorated both for tree-size and yield as compared with other rootstocks. The other promising rootstock appears to be smooth lemon, which despite the initial disadvantage of tree size, did exceedingly well later on. The performance of sweet lime rootstock was in no way different from that noticed in Fig. 3.

Comparative performance of Malta Local and Blood Red trees

Blood Red variety of sweet orange is the most popular among consumers and the market price of the fruit of this variety has always been at least 25 per cent more than that of other varieties. In spite of the higher rate for this variety, the

area under Blood Red variety has always been less than that under other varieties. The explanation for this paradox may be sought by comparing the data regarding these two varieties as shown in Table VIII.

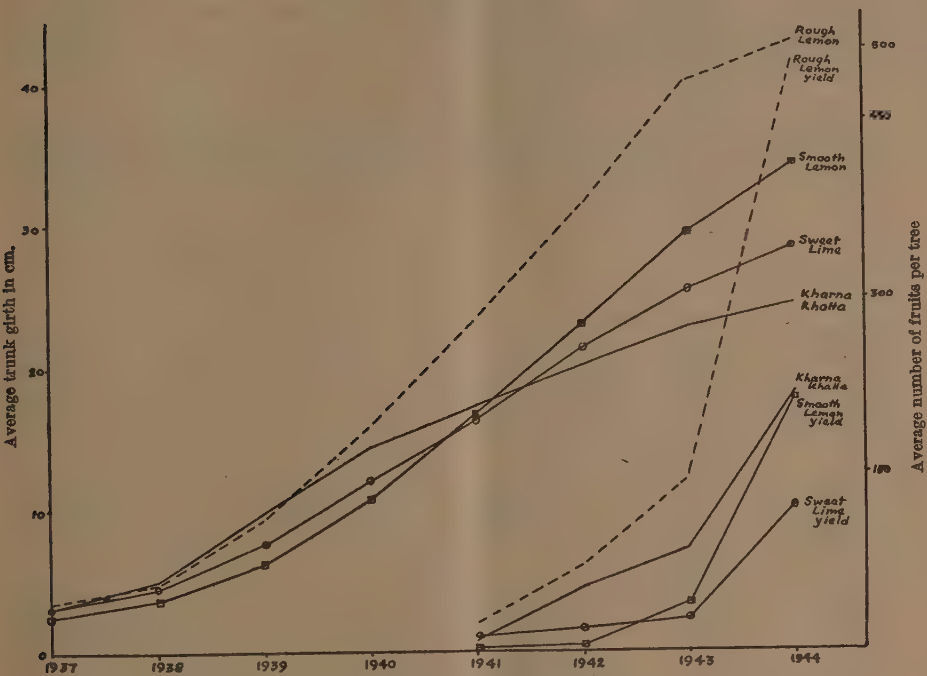

FIG. 4. Tree-size and cropping of Malta Blood Red on cutting rootstocks

It is clear from Table VIII that the trees of Blood Red variety are much smaller in size in spite of their being of the same age as those of the Malta Local variety. From the point of view of cropping, however, Blood Red variety does not appear to be a shy bearing one, at least in the first few years of cropping. In fact, the trees of this variety have borne better crops than Malta Local on rough lemon stock propagated from cuttings. It is, however, probable that this variety may not eventually compare favourably with Malta Local which has a good performance both for growth and cropping. Blood Red variety, on the contrary appears to be more precocious, though it may not come to be a better cropper than Malta Local. Out of the five rootstocks under trial, rough lemon has proved compatible with both the varieties of sweet orange. It is significant to note that for better tree-size and more yield, Malta Local and Blood Red varieties should be propagated on rough lemon rootstock raised from cuttings.

TABLE VIII

The size and cumulative yield of Malta orange trees growing on certain rootstocks raised from seed and cuttings

Rootstock under study	Method of raising the rootstock	Variety of Malta orange	1941		1942		1943		1944	
			Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield
Kharna khatta	Seed	Malta Local	25·5	9	32·9	52	39·2	140	44·4	340
	Seed	Malta Blood	14·8	0	19·1	11	22·8	38	26·1	104
	Cutting	Malta Local	27·3	15	34·9	87	41·5	180	46·4	416
	Cutting	Malta Blood	17·3	8	20·1	55	22·9	89	24·4	218
Rough lemon	Seed	Malta Local	23·4	0	31·2	15	37·7	63	43·1	203
	Seed	Malta Blood	19·5	0	27·1	3	34·9	9	42·0	170
	Cutting	Malta Local	27·5	10	35·9	56	43·5	119	49·5	368
	Cutting	Malta Blood	23·8	25	31·6	76	38·4	148	42·9	500
Sweet lime	Seed	Malta Local	19·1	3	25·1	26	28·0	32	30·8	97
	Seed	Malta Blood	14·5	2	19·1	10	23·3	20	27·3	59
	Cutting	Malta Local	21·9	7	27·9	42	33·6	56	37·2	210
	Cutting	Malta Blood	16·7	9	21·5	16	25·6	24	28·6	123
Citron	Seed	Malta Local	18·0	4	21·6	27	24·6	42	26·9	92
	Seed	Malta Blood	12·9	1	16·5	6	19·9	19	22·7	104

Statistical treatment of data in Tables IV and VII

Study of growth rates. The data reported in the previous section give an idea about the size of trees at the time of observation, but do not provide any idea of the nature and rate of growth that might be expected in subsequent years. In order to have a precise estimate of the rate of growth, the data were studied statistically. Such a study is most important from an academic point of view but it is also of some practical value as it is possible to discern trends and formulate a basis about the growth behaviour that might be expected in future years. It also gives an idea about the rate at which the trees grow from year to year, eliminating the variations due to seasonal and environmental factors and, as such, an idea about the inherent capabilities of the material is indicated.

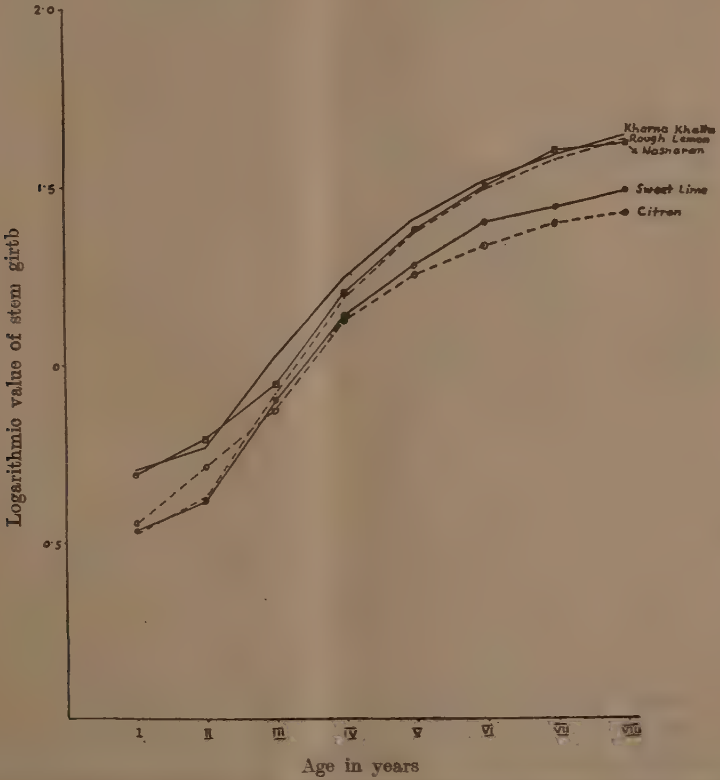

FIG. 5. Growth curve of Malta Local scion variety raised on apogamic seedling root stocks

In order to study growth rates the logarithmic values of girth, taken at different intervals, were calculated and plotted on a graph paper. The curves so obtained are shown graphically in Fig. 5 to 8 and are expressed mathematically by the exponential equation.

$y = a + Kt$ where
y = log of girth in cm.
a = log of theoretical girth at the start in the orchard.
t = time in years from the beginning of the experiment.
$K = b \log e$ where b is the relative rate of growth per year.

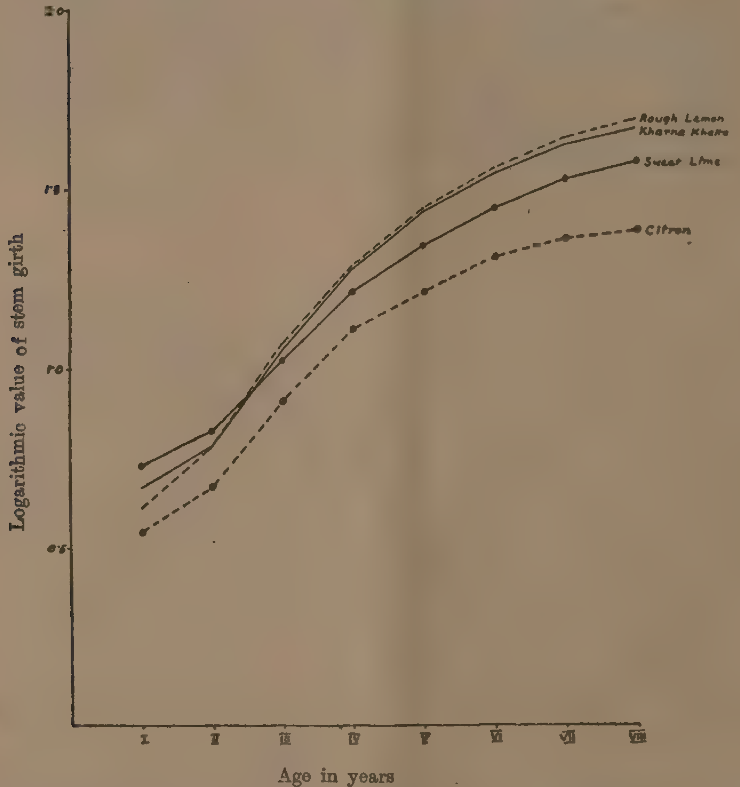

FIG. 6. Growth curve of Malta Local scion variety on various rootstock raised from cuttings

A general curve was fitted to the data by the method of orthogonal polynomials and it was found that sum of squares due to regression co-efficients contributed by terms higher than the quadratic was so small as to be negligible and hence the curve was fitted up to quadratic only. The analysis of variance of the sum of squares contributed by the regression co-efficients in the curve was compiled separately for the girth data reported in Tables II, III, V and VI.

(a) *Malta Local.* The sums of squares contributed by regression co-efficient in the curve for girth data of Malta Local scion on apogamic seedlings and vegetatively propagated rootstocks is given in Table IX.

TABLE IX

Analysis of variance due to regression coefficien

	Method of raising the rootstock	D.F.	Rough lemon		*Kharna khatta*		Sweet lime	
			S. S.	M. S.	S. S.	M. S.	S. S.	M. S.
Linear	Seed	1	1·23212254	1·23212254‡	0·91516724	0·91516721‡	0·92226341‡	0·92226341‡
Quadratic	,,	1	0·04406932	0·04406932†	0·02590620	0·02590620†	0·04724512	0·047245121‡
Cubic	,,	1	0·00854752	0·00854752	0·00772628	0·00772628	0·00650534	0·00650534
Residual	,,	4	0·00902893	0·00225723	0·00820655	0·00205164	0·00923671	0·00230918
TOTAL		7	1·29376831	..	0·95700727	..	·98525058	..
Linear	Cutting	1	1·07942811	1·07942811‡	0·96742139	0·96742139‡	0·68840968	0·68840968‡
Quadratic	,,	1	0·04992842	0·04992842‡	0·04024429	0·04024429‡	0·01752771	0·01752771‡
Cubic	,,	1	0·00134371	0·00134371	0·00455172	0·00455172	0·00344163	0·00344163
Residual	,,	4	0·00363729	0·00090932	0·00634811	0·00158703	0·00275629	0·00068907
TOTAL		7	1·13433753		1·01856551		0·71213531	

†=Significant at 5 per cent level
‡=Significant at 1 per cent level

TABLE IX—(*contd.*)

Analysis of variance due to regression coefficient

	Method of raising the rootstock	D.F.	Citron		*Nasnaran*	
			S. S.	M. S.	S. S.	M. S.
Linear	Seed	1	0·71656305	0·71656305‡	0·97549722	0·97549722‡
Quadratic	,,	1	0·03963064	0·03963064‡	0·01007346	0·01007346†
Cubic	,,	1	0·00243213	0·00243213	0·00828240	0·00828240
Residual	,,	4	0·00478640	0·00119660	0·00433044	0·00108261
TOTAL		7	0·76341222		0·99818352	
Linear	Cutting	1	0·66942795	0·66942795‡		
Quadratic	,,	1	0·04602555	0·04602555‡		
Cubic	,,	1	0·00167963	0·00167963		
Residual	,,	4	0·00415706	0·00103927		
TOTAL		7	0·72129019			

†=Significant at 5 per cent level
‡=Significant at 7 per cent level

The data in Table IX show that both linear and quadratic components of the curve are highly significant at 1 per cent level whereas the cubic component is not significant even at 5 per cent level of significance. The growth equations, as obtained for various rootstocks, are given in Table X.

TABLE X

Exponential equations for the growth of Malta Local scion

Rootstocks	Equations for seedling stocks	Equations for cutting stocks
Rough lemon	$y = 0{\cdot}1544 + 0{\cdot}3168t - 0{\cdot}0162t^2$	$y = 0{\cdot}2794 + 0{\cdot}3152t - {\cdot}0172t^2$
Kharna khatta	$y = 0{\cdot}3873 + 0{\cdot}2594t - 0{\cdot}0124t^2$	$y = 0{\cdot}3100 + 0{\cdot}2913t - {\cdot}0155t^2$
Sweet lime	$y = 0{\cdot}2843 + 0{\cdot}2388t - 0{\cdot}0101t^2$	$y = 0{\cdot}4812 + 0{\cdot}2198t - {\cdot}0102t^2$
Citron	$y = 0{\cdot}2690 + 0{\cdot}2688t - 0{\cdot}01536t^2$	$y = 0{\cdot}2467 + 0{\cdot}2756t - {\cdot}0166t^2$
Nasnaran	$y = 0{\cdot}4229 + 0{\cdot}2221t - 0{\cdot}00774t^2$	

Value of C. D. for ' a ' at 5 per cent $= 0{\cdot}1108$ Value of C. D. for ' a ' at 5 per cent $= 0{\cdot}1247$
$Y = a + Kt$

It is evident from Table X that the value of K or the relative rate of growth goes on decreasing in case of all the rootstocks, though the rate of decrease is more in case of the vegetatively propagated rootstocks as compared with the apogamic seedling rootstocks, showing thereby that the trees on vegetatively propagated rootstocks would reach their maximum growth early in life than the trees on seedling rootstocks. The values of ' a ' also appear to be the highest in case of vegetatively propagated stocks. It is also seen that irrespective of the method of propagation of rootstocks, the value of ' a ' appears to be higher in respect of *kharna khatta* and sweet lime rootstocks, showing thereby that these rootstocks make better growth in the nursery. The value of 'a' for *nasnaran* is the highest showing that this rootstock, when raised from seed, gives the best nursery performance and, as such, might be of special interest to the nurserymen. The growth equation, however, shows that the linear rate of change in this case is much less than that in case of other rootstocks, which means that increase is the least in this case, but the quadratic rate of change is still much less with the result that this increase is less rapid than in case of other rootstocks during the first few years, but is much more than in case of other stocks after that period. This suggests that trees on *nasnaran* should receive a much greater shock in transplanting as compared with other stocks and, in fact, this was actually experienced and the mortality in transplanting was the highest in case of this rootstock. On the other hand, nursery trees on this rootstock would grow to saleable size earlier than in case of others which is a significant advantage in raising nursery plants. Rough lemon has a very low value of ' a ' when propagated from seeds, but this value is rather high when it is raised from cuttings. The other rootstock, viz., citron has a low value of 'a' when propagated from cuttings, but relatively

high value when propagated from seed. In commercial practice, these rootstocks are almost invariably propagated from seed and, as such, the preference of citron to rough lemon by nurserymen is quite evident.

The value of K or the relative rate of growth per year as given by the abovementioned equation are set out in Table XI.

TABLE XI

Relative rate of growth of Malta Local scion growing on various rootstocks

Rootstocks	K for 'seedling stocks'	K for 'cutting stocks'
Rough lemon	0·3168—0·0162t	0·3152—0·0172t
Kharna khatta	0·2594—0·0124t	0·2913—0·0155t
Sweet lime	0·2388—0·0101t	0·2198—0·0102t
Citron	0·2688—0·0154t	0·2756—0·0166t
Nasnaran	0·2221—0·0077t	

The above-mentioned equation shows that with the passage of time the value of K decreases at the same rate in the case of citron rootstocks as in the case of rough lemon in spite of the fact that the initial rate of increase is much lower in case of citron. This would explain the inferiority of citron compared with rough lemon in so far as the tree growth is concerned. In order to have an idea about the actual performance, the relative rate of growth per cm. of girth in case of various rootstocks has been worked out for the entire period of experiment and is presented in Table XII.

The means in Table XII do not give a precise idea of the mean rate of growth as the growth in each year is the function of initial growth made during the first year and the relative rate of growth given in Table XI for the year and as such the actual mean rates of growth would be slightly different from those given in Table XII. The means along with the initial growth, however, would give a comparative idea of the performance of various stocks.

The data in Table XII show that the apogamic rootstocks of rough lemon and sweet lime induced better growth rate in the scion as compared with the vegetatively propagated rootstocks and this difference continued to increase year after year. In respect of citron and *kharna khatta* rootstocks, however, the growth rate of scion was higher on vegetatively propagated rootstocks, but this was so only up to the fifth year in the case of citron whereas in the case of *kharna khatta* the growth rate continued to be more throughout the period of study but the difference in growth rate declined with increase in the age of trees. This suggests that rootstocks raised from seed may be better than the vegetatively propagated rootstocks so far as the growth of scion is concerned.

TABLE XII

Relative rate of growth of Malta Local scion growing on various rootstocks from year to year

Year	Rough lemon		*Kharna khatta*		Sweet lime		Citron		*Nasnaran*
	Seed	Cutting	Seed	Cutting	Seed	Cutting	Seed	Cutting	Seed
1st year (1937)	0·7022	0·6862	0·5687	0·6351	0·5266	0·4826	0·5836	0·5964	0·4936
2nd year (1938)	0·6649	0·6466	0·5402	0·5994	0·5033	0·4591	0·5482	0·5581	0·4758
3rd year (1939)	0·6276	0·6070	0·5116	0·5637	0·4801	0·4356	0·5128	0·5198	0·4579
4th year (1940)	0·5093	0·5674	0·4831	0·5280	0·4568	0·4122	0·4775	0·4816	0·4401
5th year (1941)	0·5580	0·5278	0·4545	0·4923	0·4336	0·3887	0·4421	0·4434	0·4233
6th year (1942)	0·5157	0·4882	0·4260	0·4566	0·4103	0·3652	0·4067	0·4052	0·4045
7th year (1943)	0·4783	0·4485	0·3974	0·4209	0·3874	0·3417	0·3714	0·3669	0·3867
TOTAL	4·1320	3·9717	3·3815	3·6960	3·1981	2·8851	3·3413	3·3714	3·0809
Mean	0·5903	0·5674	0·4831	0·5280	0·4569	0·4122	0·4773	0·4816	0·4401

The mean rate of growth was the highest in case of rough lemon followed by that of *kharna khatta*. *Nasnaran* showed the least mean rate of growth except for vege-

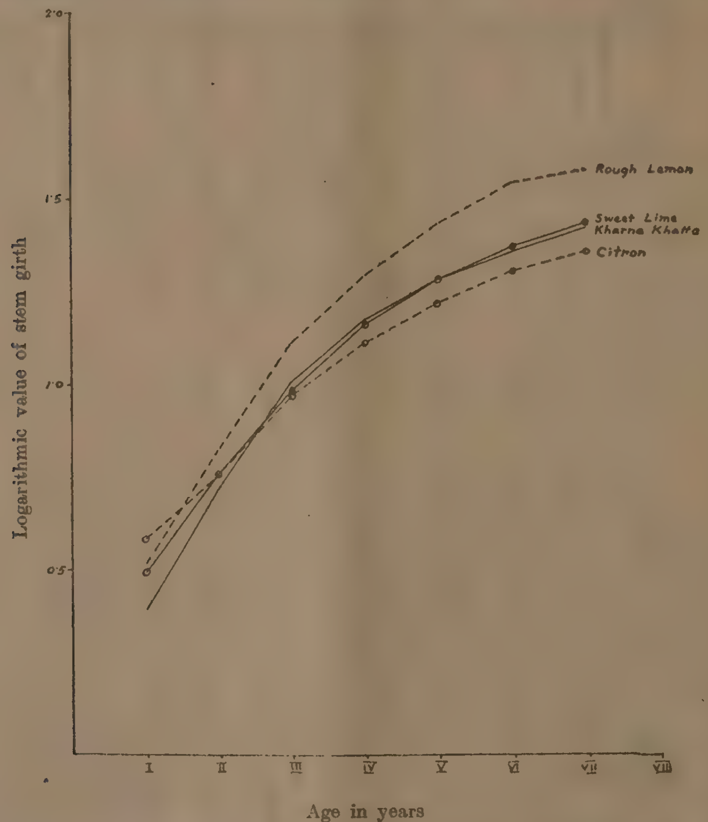

Fig. 7. Growth curve of Malta Blood scion variety raised on various apogamic seedling rootstocks

tatively propagated sweet lime rootstock. The study of growth rate from year to year, however, showed that whereas the rate of growth was the least in the first year, it was higher than that of sweet lime and citron rootstocks in the seventh year.

The diffrence in growth rate in case of this rootstock on the one hand and rough lemon and *kharna khatta* on the other, narrowed down from year to year and was very little by the end of seventh year. It has been previously stated that the initial growth, in the nursery stage, was the highest in case of this rootstock and subsequently the trees on this rootstock received the greatest setback when transplanted in the field with the result that the relative growth rate was the least in this case. Although the rate of growth has been calculated on the basis of data for the last

seven years and as such the information is most reliable for this period of the experiment, the curve can also be extrapolated to some extent and this would suggest the ultimate superiority of *nasnaran* and inferiority of sweet lime and citron rootstocks.

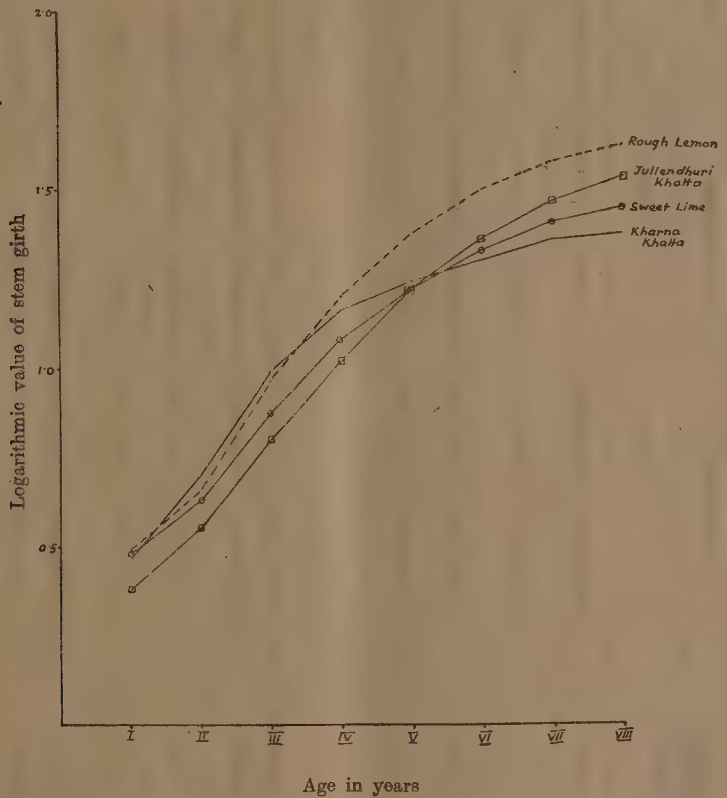

FIG. 8. Growth curve of Malta Blood scion variety on various rootstocks raised from cuttings

(*b*) *Malta Blood Red.* The sum of squares contributed by regression coefficients in the curve for girth data regarding apogamic seedlings and vegetatively propagated rootstocks are given in Table XIII.

It would be seen that in case of all the rootstocks both linear and quadratic components are highly significant even at 1 per cent level of significance, but the cubic component is not significant except in case of vegetatively propagated smooth lemon rootstock. The exponential equations, as obtained for different rootstocks are given in Table XIV.

TABLE XIII

Analysis of variance due to regression coefficient

	Method of raising the rootstock	D.F.	Rough lemon		*Kharna khatta*		Sweet lime	
			S. S.	M. S.	S. S.	M. S.	S. S.	M. S.
Linear	Seed	1	0·91799594	0·091799594‡	0·76117841	0·7611841‡	0·65897570	0·65897570‡
Quadratic	Do.	1	0·05161874	0·05161874‡	0·07231254	0·72312254‡	0·03614651	0·03614651‡
Cubic	Do.	1	0·00071723	0·00071723	0·00016700	0·00016700	0·00018040	0·00018040
Residual	Do.	3	0·00045818	0.00015273	0.00224687	0·00074896	0·00014112	0·00004704
		6	0·97079009		0·83590482		0·69544373	
Linear	Cutting	1	1·21456518	1·21456518‡	0·67966780	0·67966780‡	0·89182967	0·89182967‡
Quadratic	Do.	1	0·06192768	0·6192768‡	0·08527064	0·08527064‡	0·3943123	0·0394323‡
Cubic	Do.	1	0·00205578	0·00205578	0·00166654	0·00166654	0·00154764	0·00154764
Residual	Do.	4	0·00430150	0·001075638	0·00456877	0·00114219	0·00219040	0·00054760
		7	1·28285014		0·77117375		0·93499894	

‡ Significant at 1 per cent. level

TABLE XIII—(*contd.*)

Analysis of variance due to regression coefficient

	Method of raising the rootstock	D.F.	Citron		Smooth lemon	
			S. S.	M. S.	S. S.	M. S.
Linear	Seed	1	0·47695142	0·47695142‡		
Quadratic	Do.	1	0·02166429	0·02166429‡		
Cubic	Do.	1	0·00000726	0·00000726		
Residual	Do.	3	0·00109257	0·00036419		
		6	0·49971554			
Linear	Cutting	1			1·26465888	1·26465888‡
Quadratic	Do.	1			0·03147441	0·03147441‡
Cubic	Do.	1			0·00379167	0·00379167†
Residual	Do.	4			0·00135164	0·00033791
		7			1·30127660	

‡ Significant at 1 per cent level   † Significant at 5 per cent level

TABLE XIV

Exponential equations for the growth of Malta Blood scion

Rootstocks	Equations for seedling stocks	Equations for cutting (vegetatively propagated) stocks
Rough lemon	$y=0{\cdot}1452+0{\cdot}3795t-0{\cdot}0248t^2$	$y=0{\cdot}1271+0{\cdot}3428t-0{\cdot}0192t^2$
Kharna khatta	$y=0{\cdot}0086+0{\cdot}3993t-0{\cdot}0293t^2$	$y=0{\cdot}1676+0{\cdot}3297t-0{\cdot}0225t^2$
Sweet lime	$y=0{\cdot}1889+0{\cdot}3190t-0{\cdot}0207t^2$	$y=0{\cdot}1755+0{\cdot}2835t-0{\cdot}0153t^2$
Citron	$y=0{\cdot}3110+0{\cdot}2593t-0{\cdot}0161t^2$	
Smooth lemon		$y=0{\cdot}1618+0{\cdot}1664t+0{\cdot}0205t^2-0{\cdot}0025t^3$

Value of C.D. for 'a' at 5 per cent=0·1748 Value of C.D. for 'a' at 5 per cent=0·0294

From a glance at the equations in Table XIV it is noticed that the value of 'a' or the nursery performance of sweet lime and citron is better than that of other rootstocks irrespective of the method of propagation of these rootstocks. This is in substantial agreement with the behaviour of these rootstocks with Malta Local as the scion. The seedling rootstocks have, however, shown better nursery performance than the 'cutting rootstocks' when Malta Blood Red was used as the scion except in case of *kharna khatta* rootstock. The initial value of 'K' or the relative rate of growth is also higher in case of seedling rootstocks which, however, goes on decreasing rather rapidly. As previously mentioned, it was just the reverse in case of Malta Local scion. This shows that in a rootstock trial, it is not sufficient to limit the scope to testing only the species for mutual compatability, but the horticultural varieties of the species must also be tested.

A study of the equations for various rootstocks shows that the behaviour of smooth lemon is very much different from that of other rootstocks. In this case, the rate of growth which is very low in the beginning, rises rapidly after some years and utlimately decreases even more rapidly.

On the basis of data for the first five years, it was mentioned in a previous communication that in case of vegetatively propagated rootstocks with the sole exception of *kharna khatta* and with the exception of citron only when the trees were propagated on apogamic rootstocks, the growth was linear, but here, it may be noticed that in respect of these treatments also, the rate of growth decreases as the trees advance in age. The value of 'a' in case of seedling rootstocks for the data for more years works out to be substantially the same as with data for fewer years reported in the previous communication [Sham Singh and Nagpal, 1947] but this has been modified to some extent in case of vegetatively propagated rootstocks.

The value of 'K' or the relative rate of growth as given by the above-mentioned equations is set out in Table XV.

TABLE XV

Relative rate of growth of Blood Red scion growing on various rootstocks

Rootstocks	'K' for seedling stocks	'K' for 'cutting' stocks
Rough lemon	0·3795—0·0248t	0·3428—0·0192t
Kharna khatta	0·3993—0·0293t	0·3297—0·0225t
Sweet lime	0·3190—0·0207t	0·2835—0·0153t
Citron	0·2593—0·0161t	——
Smooth lemon	——	0·1664+0·0205t—·0025t²

The data in Table XV bring out clearly the inferiority of the vegetatively propagated *kharna khatta* rootstock as the rate of decrease with the passage of time in this case is most rapid amongst the vegetatively propagated rootstocks in spite of the fact that the initial rate of increase is also lower than that of rough lemon. The performance of this rootstock does not, however, appear to be so inferior when propagated from seed. The overall marked superiority of rough lemon over the remaining rootstocks is also quite clear. In case of smooth lemon, the relative rate of increase which is smaller in the beginning, increases rather rapidly after some years. In order to have a comprehensive idea about the rate of growth, the relative rate of growth, per year per cm. girth for various rootstocks has been worked out for the entire period of the experiment as given in Table XVI.

TABLE XVI

Relative rate of growth of Blood Red scion growing on various rootstocks from year to year

Year	Rough lemon		Sweet lime		Citron		Smooth lemon	
	Seed	Cutting	Seed	Cutting	Seed	Cutting	Seed	Cutting
1st year	0·8167	0·7451	0·8519	0·7073	0·6868	0·6175	0·5599	0·4245
2nd year	0·7596	0·7009	0·7844	0·6555	0·6392	0·5823	0·5229	0·4545
3rd year	0·7025	0·6567	0·7170	0·6037	0·5915	0·5470	0·4858	0·4729
4th year	0·6454	0·6121	0·6495	0·5519	0·5438	0·5118	0·4487	0·4798
5th year	0·5883	0·5681	0·5820	0·5001	0·4962	0·4766	0·4117	0·4752
6th year	0·5312	0·5240	0·5146	0·4483	0·4485	0·4414	0·3746	0·4591
7th year	0·4741	0·4752	0·4471	0·3965	0·4008	0·4062	0·3375	0·4315
TOTAL	4·5178	4·2822	4·5465	3·8633	3·8068	3·5828	3·1411	3·1975
Mean	0·6454	0·6117	0·6495	0·5519	0·5438	0·5118	0·4487	0·4568

The data in Table XVI would at once reveal the superiority of apogamic rootstocks from the very inception of this experiment whereas in case of Malta Local

scion, the vegetatively propagated rootstocks were found superior to apogamic rootstocks in the beginning and it was only in the fifth year of the experiment that apogamic seedling rootstocks began to show their superiority.

Smooth lemon started with the least rate of growth in the first year which went on increasing during the vegetative phase whereas it has been consistently decreasing in other rootstocks. It is only with the trees coming into fruiting that it began to decrease in this case. The rate of growth that was the least in the beginning of the experiment became higher than that of other rootstocks except rough lemon by the end of seventh year, showing thereby the potential superiority of this rootstock over others except perhaps the rough lemon.

The mean rate of growth for the entire period of observation was the highest in the case of rough lemon followed by that of *kharna khatta* raised from seed. This was rather low in respect of sweet lime, citron and vegetatively propagated *kharna khatta*—being especially so in the case of citron. This, coupled with the low growth rate during the entire period of observation, shows the inferiority of citron over other stocks.

Annual growth increment in relation to yield

(*a*) *Malta Local.* The need for a study of this nature has already been discussed in a previous communication [Sham Singh and Nagpal, 1947]. The data for Malta Local scion propagated on both vegetatively propagated and apogamic rootstocks are compiled in Table XVII.

The data in Table XVII show that, in all cases, the crop produced by the trees on vegetatively propagated rootstocks is more than that on apogamic rootstocks, thus showing the precocity induced by vegetatively propagated rootstocks. The growth put on by the scion was also more when it was worked on rootstocks propagated by cuttings except in the case of citron, where the reverse was the case.

The study of growth as represented by trunk-girth increment in the case of apogamic rootstocks shows that rootstocks in the first year could be divided into two groups, viz. vigour inducing rootstocks like *kharna khatta*, rough lemon and *nasnaran* and dwarfing rootstocks like sweet lime and citron. The differences in growth increment within each group were not significant while those between the two groups were significant. The differences between the two groups persisted till 1944 and the relative position of the rootstocks within the two groups was also maintained. In the second year (1941) although differences in growth increment due to various stocks were not significant, the relative position of various stocks was slightly different from that during the year 1940. In case of the vigour inducing rootstocks, *kharna khatta* which was leading for growth increment in 1940 was relegated to the second position in the following year, while *nasnaran* which made the least growth in 1940, made the maximum during 1941. These rootstocks maintained this performance during 1943 with the result that the differences between them got further magnified so much so that the growth of scion trees on *nasnaran* was significantly higher than that on *kharna khatta*, while that on rough lemon was in between that on *kharna khatta* and *nasnaran* and was not significantly different from

TABLE XVII

The mean increment in trunk girth and average yield of Malta Local trees growing on certain rootstocks raised both vegetatively and by apogamic seedlings

Rootstock under trial	Method of propagation of rootstocks	1940		1941		1942		1943		1944	
		Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield
Kharna khatta	Seed	7·2	..	7·9	9	7·3	43	6·3	88	5·2	209
do.	Cutting	7·8	..	8·2	15	7·6	72	6·6	93	5·0	236
Rough lemon	Seed	7·1	..	8·0	3	7·8	15	7·0	49	5·4	139
do.	Cutting	7·7	..	8·4	10	8·4	46	7·5	63	6·1	249
Sweet lime	Seed	5·9	..	5·2	3	5·1	23	3·9	6	2·3	66
do.	Cutting	5·8	..	5·5	7	6·1	36	5·6	13	3·7	154
Citron	Seed	6·0	..	4·4	4	3·7	23	2·9	15	2·3	50
do.	Cutting	4·7	..	3·5	22	4·0	28	2·5	25	1·1	66
Nasnaran	Seed	6·8	..	8·3	8	8·6	21	7·5	49	6·6	159
S. E.	Seed	0·223	..	0·318	1·568	0·390	4·6	0·371	15·3	0·39	20·2
S. E.	Cutting	0·289	..	0·344	4·296	0·403	5·914	0·471	13·074	0·355	32·16
C. D.	Seed	0·7	..	0·9	5	1·2	14	1·1	45	1·1	59
C. D.	Cutting	0·9	..	1·0	14	1·2	18	1·4	39	1·1	97

either of these two. The same performance was maintained in 1943, but by 1944, the growth induced by *nasnaran* was significantly more than either by rough lemon or *kharna khatta*, the differences between *kharna khatta* and rough lemon being non-significant. The crop produced in 1941 was very little and almost negligible. In the following year, however, the crop was quite substantial, being the heaviest in respect of *kharna khatta*. This was significantly higher than that on any other rootstock. In 1943 and 1944, although trees on *kharna khatta* again produced much higher yields than those on the remaining rootstocks and among these, *nasnaran* and rough lemon rootstocks induced significantly higher yields than sweet lime and citron. These data further reveal that *nasnaran* which induced the least growth increment in earlier years not only induced the greatest increase subsequently but, at the same time, gave a good performance so far as the yield was concerned. This is a point which places *nasnaran* in a superior position to other stocks under trial.

Among the rootstocks raised from cuttings, in the year 1940, when the trees did not bear any crop, the growth induced by invigorating rootstocks namely, *kharna khatta* and rough lemon was significantly more than that induced by the two dwarfing stocks namely sweet lime and citron and among the dwarfing stocks, the latter being significantly inferior to the former. In subsequent years, when substantial crop was produced, the relative position of dwarfing rootstocks both between themselves and with regard to invigorating rootstocks remained substantially the same. Amongst the invigorating rootstocks, however, even in the very first year of bearing, viz. 1941, the growth induced by rough lemon rootstock was more than that by *kharna khatta*, though the difference was not significant. The differences between the two continued to increase year after year and, by 1944, the difference became significant. In 1941, the crop was rather light, but in the following year, when a substantial crop was produced, the yield of Malta Local trees on *kharna khatta* was significantly more than that on other stocks. In 1943, however, although the yield of Malta trees induced by *kharna khatta* was still significantly higher than that on other stocks, the sweet lime and citron stocks were significantly inferior, in this respect, to rough lemon. In 1944, Malta trees on rough lemon stocks produced as good a crop as those on *kharna khatta*, but they continued to produce light crops on sweet lime and citron. This suggests that there had been a consistent improvement in the performance of Malta trees on rough lemon stock from the year the trees commenced fruiting.

It was previously observed that there had been a regular increase in the amount of growth year after year during the prebearing life of the trees. In the first year of bearing (1941), when there was a light crop, it was noticed that in case of the so-called vigorous rootstocks, viz. *kharna khatta*, rough lemon and *nasnaran*, there was an increase in the growth of scion trees during that year, whereas in case of the dwarfing rootstock, viz. sweet lime and citron, the growth of the scion had been less than in the previous year. In the following year, when the crop produced was relatively more than in 1941, the growth put on by the scion on vigorous stocks was less than in the previous year except in the case of *nasnaran*. On the whole, the increase in production was almost invariably followed by decrease in growth. In

TABLE XVIII

The relative performance of Malta Local trees on rootstocks raised both by cutting and apogamic seedlings

Rootstocks under trial	Method of propagation of rootstock	1941		1942		1943		1944	
		Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield
Kharna khatta	Seed	100	100	92	478	80	978	66	2322
Kharna khatta	Cutting	100	100	93	480	75	620	57	1573
Rough lemon	Seed	101	33	99	167	89	544	68	1544
Rough lemon	Cutting	102	67	102	307	91	420	74	1660
Sweet lime	Seed	66	33	65	256	49	67	35	733
Sweet lime	Cutting	67	47	74	240	68	87	45	1027
Citron	Seed	56	44	47	256	37	167	29	556
Citron	Cutting	43	147	49	186	30	167	13	440
Nasnaran	Seed	105	89	109	233	95	544	84	1767

order to illustrate this relationship more vividly, the mean yearly increments in girth and production have been expressed in percentages—taking the growth and yield of trees on *kharna khatta* for 1491 as the basis.

The data in Table XVIII show that in the case of apogamic seedling rootstocks. The growth increment in respect of *kharna khatta* rootstock decreased by 34 per cent in four years for an increase of 2322 per cent in fruit yield as compared with other rootstocks where the respective figures for decreased growth rate and increased yield are 33 per cent and 1544 per cent for rough lemon, 21 per cent and 1767 per cent for '*nasnaran*', 31 per cent and 733 per cent for sweet lime ; and 27 per cent and 556 per cent for citron. In order to study the efficacy of various rootstocks, it is appropriate to compare these figures after expressing them on a common basis. For every 1 per cent decrease in the growth increment of Malta trees on rootstocks *kharna khatta*, rough lemon, *nasnaran*, sweet lime and citron, the corresponding increase in fruit production is 68, 47, 84, 24 and 21 respectively. This shows the superiority of rootstocks associated with vigorous growing scion trees over those in the dwarfing group. Among the vigour inducing rootstocks, the performance of *nasnaran* appears to be the most outstanding. Similar figures in the case of rootstocks raised from cuttings are 37, 59, 47 and 34 for *kharna khatta*, rough lemon, sweet lime and citron respectively. In this case, rough lemon has given the most outstanding performance while sweet lime which gave rather poor performance when raised from seed has given comparatively better results when raised from cuttings.

(b) *Malta Blood Red*. The data for Blood Red scion propagated on rootstocks raised from apogamic seedlings and cuttings are compiled in Table XIX.

The data in this Table show the precocity of Blood Red scion on rootstocks raised from cuttings. Substantial crop was produced by Blood Red trees on apogamic seedling rootstocks only in the year 1944—the crop on these stocks during the earlier years being negligible. In the case of rootstocks raised from cuttings, however, substantial crop was produced even as early as 1942. The growth put on by this scion on 'cutting' rootstocks, on the whole, however, is less than that on 'seedling' rootstocks during the entire period of the experiment.

The trees on apogamic seedling rootstocks produced the first substantial crop in 1944, when production on rough lemon rootstock was the maximum while that on sweet lime was the minimum. The trees on citron rootstock yielded significantly better crop than those on sweet lime but definitely less than those on rough lemon or *kharna khatta*. The growth put on by the scion, during this year, was the least in the case of citron rootstock, though the differences in growth on sweet lime, *kharna khatta* and this rootstock were not significant. The growth on rough lemon rootstock, however, was significantly more than that on any other rootstock. The performance of various rootstocks, so far as the amount of growth made by the scion is concerned, has been more or less similar to that in the previous years except that the performance of rough lemon improved from year to year, and that of *kharna khâtta* and citron deteriorated with the passage of time.

TABLE XIX

The mean increment in trunk girth and average yield of Malta Blood scion growing on certain rootstocks raised from cuttings and apogamic seedlings

Rootstock under trial	Method of propagation of rootstock	1940		1941		1942		1943		1944	
		Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield
Kharnà khatta	Seed	4·9	..	4·7	..	4·3	11	3·7	27	3·4	126
Kharna khatta	Cutting	4·8	..	2·7	8	2·8	48	2·8	34	1·6	129
Rough lemon	Seed	5·9	..	6·9	..	7·6	3	7·8	6	7·0	161
Rough lemon	Cutting	6·6	..	7·7	25	7·8	47	6·8	76	4·6	353
Sweet lime	Seed	4·0	..	4·8	2	4·6	8	4·2	10	4·0	39
Sweet lime	Cutting	4·7	..	4·6	9	4·8	6	4·2	9	2·9	98
Citron	Seed	3·8	...	3·4	2	3·6	5	3·4	13	2·9	86
Smooth Lemon	Cutting	4·4	..	6·0	1	6·3	4	6·5	29	5·0	184
S.E.	Seed	0·442	..	0·28	..	0·441	2·071	0·489	3·462	0·594	14·516
S.E.	Cutting	0·185	..	0·215	4·146	0·187	4·91	0·269	6·947	0·22	11·94
C.D.	Seed	1·3	..	0·8	..	1·3	9	1·5	10	1·8	44
C.D.	Cutting	0·6	..	0·6	12	0·6	15	0·8	21	0·7	36

The trees on rootstocks raised from cuttings produced a light crop in 1941 and a substantial one in 1942 in the case of *kharna khatta* and rough lemon stocks whereas the crop on other rootstocks was a light one. In 1943, rough lemon induced significantly higher yield than other stocks. The crop induced by sweet lime was extremely poor and was significantly lighter than that on smooth lemon and *kharna khatta*. In 1944, a tremendous increase in crop resulted in the case of all the rootstocks, the increase being especially marked in the case of rough lemon. The yield of scion on smooth lemon rootstock, though much less than that on rough lemon, was significantly more than that on the remaining rootstocks. Notwithstanding the large increase in the crop induced by rough lemon rootstock, the increase in growth in this case was also significantly more as compared with *kharna khatta* and sweet lime. The growth of scion on smooth lemon which was significantly less than that on rough lemon in 1940 had been showing a consistent improvement with the result that, by 1944, the performance of these stocks reversed though the difference is not yet significant.

In the year 1940, the size of Blood Red trees on rough lemon was significantly more than that on other rootstocks—the differences amongst other rootstocks being below the significant limit. In the following year, there was no difference in the relative position of rough lemon, but among the remaining rootstocks, the scion trees made significantly more growth on smooth lemon than on *kharna khatta* and sweet lime. This position remained substantially the same in 1942 but in 1943 the growth differences between rough lemon and smooth lemon were evened up, whereas the performance of other rootstocks remained unchanged.

In order to illustrate the relationship between growth and cropping more vividly, the mean yearly increments in girth and yield in all cases have been expressed as percentages in Table XX—taking growth increment and yield of scion trees on rough lemon rootstock for 1941 as the basis. The percentages have not been worked out for 'seedling rootstocks' due to the fact that substantial crops in their case had not been produced till 1944.

TABLE XX

The relative performance of Malta Blood Red trees on rootstocks raised from the rooting of stem cuttings

Year of observation	*Kharna khatta*		Rough lemon		Smooth lemon		Sweet lime	
	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield	Girth in cm.	Yield
1941	35	32	100	100	78	4	60	36
1942	36	192	101	188	82	16	62	24
1943	36	136	88	304	82	116	55	36
1944	28	516	60	1412	65	736	38	392

The data in Table XX show that in the case of *kharna khatta*, there was a decrease of 12 per cent in growth increment and an increase of 516 per cent in yield by 1944, the corresponding figures for rough lemon, sweet lime and smooth lemon being 40 per cent and 1412 per cent, 22 per cent and 392 per cent, 13 per cent and 736 per cent respectively. When these figures are expressed on a common basis for studying the comparative efficacy of different rootstocks, it is found that for every one per cent decrease in growth increment, there was an increase of 57 per cent, 43 per cent, 35 per cent and 18 per cent in crop production in case of smooth lemon, *kharna khatta*, rough lemon and sweet lime respectively. Thus, besides rough lemon, smooth lemon appears to be another promising rootstock for the Blood Red variety. The figures for *kharna khatta* appear promising for the reason that decrease in growth in this case had started before the trees came into fruiting and, as such, the decrease in growth with increase in fruit production was rather slight.

Correlation between growth increment and cropping

(a) *Malta local.* In order to study the relationship between increment in girth and the number of fruits borne in a particular year in respect of various stionic combinations, the values of the correlation coefficient were worked out after eliminating the products due to blocks and years. The data, thus obtained, are set out in Table XXI.

TABLE XXI

The correlation coefficient between growth increment and fruit production in a particular year pertaining to the various rootstocks under trial

Name of rootstock variety	Name of scion variety	Number of pairs examined	D.F.	Expected value of correlation coefficient for P=0·05	Correlation coefficient in case of rootstocks raised from seed	Correlation coefficient in case of rootstock raised from cuttings
Kharna khatta	Malta Local	24	14	0·497	+0·285	+0·061
Kharna khatta	Malta Blood				—0·492	+0·078
Rough lemon	Malta Local				—0·135	—0·026
Rough lemon	Malta Blood				+0·143	—0·087
Sweet lime	Malta Local				—0·521	—0·423
Sweet lime	Malta Blood				+0·315	+0·214
Citron	Malta Local				+0·378	—0·264
Citron	Malta Blood				+0·032	..
Nasnaran	Malta Local				+0·057	..
Smooth lemon	Malta Blood				..	—0·273

The figures show that except in the case of Malta Local trees on sweet lime rootstock, raised from seed, there is no correlation between the growth made and the crop produced in a particular year. In other words, irrespective of the kind of rootstock used, the growth and cropping appear to be quite independent of each other. The data in Tables XVII and XIX, however, show that for all the stionic combinations under trial, the increase in cropping is associated with a corresponding decrease in the amount of growth made. This anomaly appears to be due to the fact that certain minor variations obtaining from year to year might have affected these results. In order to eliminate these variations, the correlation was worked out as obtaining during the entire period of four years and the results, thus obtained, are given in Table XXII.

TABLE XXII

Correlation coefficient between growth increment and fruit yield for the four year period from 1940-41 to 1943-44

Name of rootstock variety	Name of scion variety	Number of pairs examined	D.F.	Expected value of correlation co-efficient for P = ·05	Correlation co-efficient for rootstocks raised from seed	Correlation co-efficient in case of rootstocks raised from cuttings
Kharna khatta	Malta Local	24	17	0·456	—0·866	—0·823
Kharna khatta	Malta Blood				—0·674	—0·608
Rough lemon	Malta Local				—0·777	—0·797
Rough lemon	Malta Blood				—0·566	—0·943
Sweet lime	Malta Local				—0·734	—0·841
Sweet lime	Malta Blood				—0·127	—0·893
Citron	Malta Local				—0·418	—0·525
Citron	Malta Blood				—0·45[9]	..
Nasnaran	Malta Local				—0·751	..
Smooth lemon	Malta Blood				..	—0·726

The negative correlations for all the stionic combinations establish the view that an increase in fruit production is invariably accompanied by a decrease in growth during a particular period. It is also clear that the correlations are much higher in respect of cutting rootstock except in the case of *kharna khatta*. This may be due to the precocity of trees on rootstocks raised from cuttings. It would also be observed that in the case of the Blood Red variety on sweet lime propagated from seed there is almost no correlation while there is only a fair amount of correla-

tion in respect of other rootstocks. This might be explained by the fact that the crop borne on this set of rootstocks was substantial only in 1944 and that during the remaining three years it was rather light. Thus, the increase in growth during these three years was not affected by the light crop yields but was so affected only by the inherent capacity of the rootstocks used. In the remaining stionic combinations except when citron is used as a rootstock, there is a very high correlation. It has already been stated that the growth of scion trees on citron rootstock is deteriorating and the fact that this decrease in growth increment is not accompanied by a corresponding increase in fruit production suggests its unsuitability for the scion varieties under trial here.

With the commencement of fruit bearing, there had been a decrease in the amount of growth made by the scion trees from year to year with a corresponding increase in crop production. In order to evaluate the relative efficiency of various rootstocks, it is most desirable to study the manner in which an unit decrease in growth has been reflected in increased crop production. This is best brought out by calculating the regression coefficients for various stionic combinations under trial. The figures, thus obtained, are set out in Table XXIII.

TABLE XXIII

Regression coefficient of growth increment on yield of trees for the period 1940-41 to 1943-44

Name of rootstock variety	Name of scion variety	Regression coefficient for rootstocks raised from seed	Regression coefficient for rootstock raised from cutting
Kharna Khatta	Malta Local	—64	—61
Kharna khatta	Malta Blood	—67	—43
Rough lemon	Malta Local	—39	—77
Rough lemon	Malta Blood	—85	—94
Sweet lime	Malta Local	—18	—61
Sweet lime	Malta Blood	—4	—47
Citron	Malta Local	—11	—14
Citron	Malta Blood	—29	..
Nainaram	Malta Local	—55	..
Smooth lemon	Malta Blood	..	—75

The figures in Table XXIII showed that during the first four years of fruiting of Malta Local and Blood Red trees, the rootstock raised from cuttings proved more

efficient than those raised from seeds. In the case of *kharna khatta* rootstocks, especially with Blood Red as the scion, however, the rootstocks propagated from seed gave much better performance than those raised from cuttings.

On the whole, the performance of rough lemon had been the most outstanding, while that of citron had been the most disappointing. The performance of sweet lime, especially when it was propagated from seed, also appeared to be unsatisfactory. The performance of *kharna khatta* which was the best in the case of Malta Local scion was most disappointing in case of the Blood Red variety especially when the rootstock was propagated from cuttings. The performance of *nasnaran* and smooth lemon appeared, so far, to be quite encouraging.

Summary

1. The influence of certain rootstocks, propagated both from seeds and cuttings, on tree vigour and cropping of two varieties of sweet orange, viz. Malta Local and Malta Blood Red has been studied for a period of four years.

2. The vegetatively raised rootstocks proved more precocious as compared with the seedling rootstocks in respect of both the scion varieties under study.

3. The vegetatively raised rootstocks with the exception of citron induced better tree-size of the Malta Local variety in the vegetative phase and this characteristic also persisted during the first four years of cropping.

4. The initial advantage of tree-size in favour of the Blood Red variety on vegetatively propagated rootstocks also persisted during the entire period of four years as in the case of the Malta Local variety except that, by 1944, the tree size on *kharna khatta* deteriorated when it was raised from cuttings.

5. The vegetatively raised rootstocks induced consistently higher yields as compared with the seedling rootstocks in case of both the scion varieties under study and over the entire period of these trials.

6. For every one per cent decrease in the growth increment of Malta Local trees on rootstocks *kharna khatta*, rough lemon, *nasnaran*, sweet lime and citron, the corresponding increase in fruit production was 68 per cent, 47 per cent, 84 per cent, 24 per cent and 21 per cent respectively. This shows the superiority of rootstocks associated with vigorous growing scion trees over those in the dwarfing group and amongst the vigour inducing rootstocks the performance of *nasnaran* appears to be the most outstanding.

7. For every one per cent decrease in the growth increment of Malta Blood Red trees on rootstocks smooth lemon, *kharna khatta*, rough lemon and sweet lime, the corresponding increase in fruit production was 57 per cent, 43 per cent, 35 per cent and 18 per cent respectively. Thus, besides rough lemon, smooth lemon appears to be another promising rootstock for the Blood Red variety.

8. In the case of Malta Local variety, *kharna khatta* gave the most outstanding performance so far as the cropping was concerned, having taken the lead from the first year of crop production. It was followed closely by *nasnaran* and rough lemon.

The other two rootstocks, viz. sweet lime and citron proved far inferior to the rest.

9. The performance of *kharna khatta* which was the best in the case of Malta Local scion was disappointing in the case of Malta Blood Red variety especially when the rootstock was propagated from cuttings.

10. On the whole, the performance of rough lemon had been the most outstanding in respect of both the scion varieties while that of citron had been the most disappointing.

11. Age for age, the trees of the Blood Red variety remained smaller in size than those of the Malta Local variety. They were, however, more precocious.

12. The high negative correlations for all the stionic combinations establish the view that an increase in fruit production is invariably accompanied by decrease in growth during a particular period.

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FIXATION OF NITROGEN FROM AMMONIUM SULPHATE BY INDIAN SOILS

By Abhiswar Sen, Indian Agricultural Research Institute, New Delhi

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THE compounds of nitrogen, used as fertilisers, are very unstable in nature; either they are freely soluble in water and are likely to be lost through leaching by rain and irrigation water and or get oxidised through various chemical reactions. The peculiar nature of the nitrogen in soil makes the study of its behaviour in the soil interesting.

Both the organic and the inorganic colloidal constituents of the soil have the power of absorbing bases and in addition, it is likely that a part of the nitrogen in the form of ammonium ion or ammonia may also be fixed. A study of the absorption of the ammonium nitrogen is, therefore, important from the point of view of fertiliser practices in agriculture.

Peck [1911] considered that the fixed ammonia must be oxidised to nitrate before any appreciable leaching of the nitrogen could take place. Cook [1919] observed that a slightly alkaline reaction of the soil was beneficial for the conservation of ammonia. Porges [1929] found that a portion of the nitrogen, in the form of ammonium salts, applied to the soil, rapidly changed to a form which could not be easily leached out. He suspected formation of some insoluble organic ammonium complexes. This would probably account for Carleton's observations [Carleton, 1945] on the persistence of ammonium nitrogen against leaching in a soil receiving high rainfall.

Apart from the loss of nitrogen from soils by leaching, with applications of nitrogenous fertilisers, there is also the loss by volatilisation. Jewit [1942] reported appreciable losses of nitrogen in soils with pH values higher than 7·0 but little loss in soils with pH values lower than it. It has been surmised that loss of nitrogen this way may be a general phenomenon in all tropical soils [Sreenivasan, 1944]. Most of the ammonia added in the form of ammonium sulphate might be lost in this form within a fortnight [Subrahmanyan, 1937].

During the present investigation, absorption of ammonium nitrogen from ammonium sulphate, by soils from different parts of India has been studied by a new method. In the method followed, a longer time has been allowed for the interaction between the soil and the ammonium sulphate and the observations made under conditions resembling to a certain extent, actual fertiliser practices.

Methods and materials

Methods

The quantities of nitrogen, absorbed in the form of ammonia on treatment of soils with ammonium sulphate after 24 hours were determined by leaching them

with water and estimating the ammonia contents of the leachates. The studies were conducted with 19 surface soils (one foot) with varied composition and collected from different parts of India.

Two hundred gram lots of soil were taken in soil percolators [Puri 1928]. The diameter of the percolators was such that 500 c.c. of water reached a height of about five inches. Ammonium sulphate was added to the soil in the form of solution of known strength. After addition of the solution, CO_2 free distilled water was added to make the moisture content of the soil, equivalent to 50 per cent of its moisture holding capacity. The moist soil in the percolators was left undisturbed overnight to allow interactions between the soil and the ammonium sulphate to proceed. It was then leached with 500 c.c. of distilled water. The leachates were collected and excess ammonia, i.e. the portion not absorbed by the soil was estimated by distillation of the leachate with ignited MgO. The amount of water taken for leaching the soil was generally found sufficient to remove all free ammonia as evidenced from Nessler's test.

The amounts of NH_4-N fixed by the soil were calculated from the difference in the amounts of NH_4-N between NH_4-N in the amounts originally added and the amounts found in the leachates.

NH_4-N (calculated in mg. N per 100 gm. of soil) supplied (abscissae) was plotted against NH_4-N fixed (ordinates). The points corresponding to supplied NH_4-N which were completely absorbed could be joined in a straight line as also the points corresponding to NH_4-N supplied which were incompletely absorbed into another. The straight lines intersected at a point F (Fig. 1A). The amounts of nitrogen fixed by the soils corresponding to this point were termed, for convenience of expression, the nitrogen fixing capacities (F) of the soils. They represented, therefore, the limits of application of ammonium nitrogen below which there was no leaching of nitrogen and all quantities of nitrogen supplied were completely absorbed and above which the supplied nitrogen would not be completely absorbed and loss of some nitrogen by leaching would take place. There was no ammonia in the water leachate when amounts corresponding to the points A, B and C were added to the soil, so that the whole quantity of the supplied nitrogen was absorbed ; at the points D, E and G, a portion only of the added nitrogen was absorbed and the unabsorbed portion drained away on leaching with water.

It would be necessary, for a more critical determination of the point F, to find out the absorption values of ammonium nitrogen at some points in the neighbourhood of F. For the sake of convenience of determination of F, however, the detailed procedure was omitted during the present studies.

Soils

A description of the soils studied, together with their physical and chemical composition is given in Appendix I.

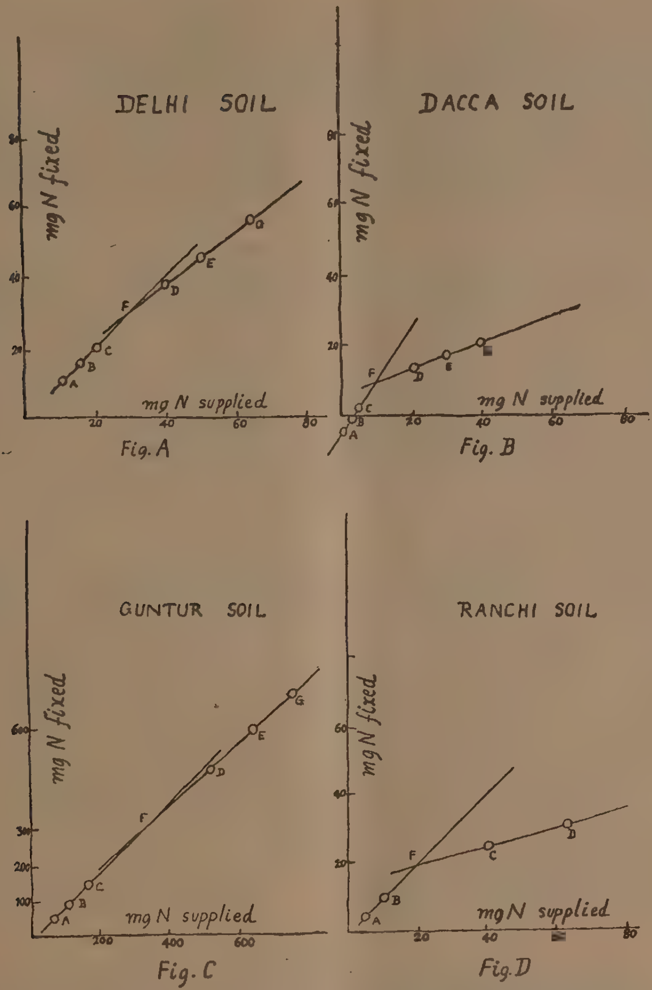

FIG. 1. Fixation of nitrogen from ammonium sulphate in different soils

DATA AND DISCUSSION

Determination of nitrogen fixation in Delhi, Guntur and Dacca soils

Working with Delhi soil, a light and a nearly neutral soil, it was found that, up to a certain limit, there was no ammonium nitrogen in the water leachate, i.e. whatever ammonium nitrogen was supplied, was completely absorbed. When the supply of nitrogen was increased further above the limit, nitrogen appeared in the leachate.

It was found that the points A, B and C could all be joined together as also D, E, and G in the incomplete absorption region in different straight lines. The two straight lines ABC and DEG, when produced, met at F, which denoted the maximum amount of ammonium nitrogen, when supplied was completely absorbed. The curve (supplied ammonium N-fixed ammonium N) assumed the form given in Fig. 1A.

A similar curve was obtained with a heavy and somewhat alkaline soil from Guntur with the difference that the arm of the curve in the incomplete absorption region was more steep and that the value of F was much higher (Fig. 1C).

Working with an acid and alluvial soil from Dacca, it was found that excess ammonia appeared in the leachate even when the soil was supplied with much smaller amounts of NH_4-N and that the excess NH_4-N exceeded the amount supplied. It was found out that a certain amount of ammonium nitrogen drained out when Dacca soil was leached with water alone. Thus, it was not that Dacca soil, when treated with ammonium sulphate, failed to absorb NH_4-N but it absorbed and released what could be leached out with water alone. Presence of ammonium salts (or humates) in the soil itself might be making this process different with smaller applications of NH_4-N, but a similar curve like the other two cases was observed by joining the points in two different regions (Fig. 1B).

Reproducibility of results

In the subsequent determinations of F, only two points in the complete absorption region and two points in the incomplete absorption region were taken. For the first two, smaller amounts of NH_4-N were supplied and in the selection of the latter two, a good difference in the supplied nitrogen was maintained. The first two and the second two were joined separately to obtain two different straight lines and the point of intersection of the lines was taken to be F (Fig. 1D). In most cases, the first two points corresponded to 4 and 8 mg. of nitrogen and the second two, 40 and 80 mg. per 100 gm. of soil. In the case of some heavy soils like Guntur, all the four points fell in one line. Some other points corresponding to, say 320 and 640 mg. of nitrogen had to be taken. Values of F were generally rounded up to the nearest digits for the sake of convenience.

Values of F determined separately with the same soils, i.e. those from Delhi, Guntur and Dacca are given in Table I.

TABLE I

Values of nitrogen fixing capacities (F) in mg. per 100 gm. of soil

No. of determinations	Soil from		
	Delhi	Guntur	Dacca
1	30	310	9
2	29	320	8
3	32	300	[illegible]

NH_4-N contents of the soils studied

All soils contain variable amounts of ammonium nitrogen depending upon their contents of organic matter, moisture, reaction, etc. Before the soils were used in the percolators, their water soluble and N NaCl soluble NH_4-N contents were determined. The values are given in the Appendix II. It would be apparent that, excepting in some acid soils, the amounts of NH_4-N already present in the soils were almost negligible and did not, in any way, prejudice the conclusions drawn from the results obtained. This was even so in acid soils.

Absorption of NH_4-N from ammonium sulphate by the soils studied

Results of determination of absorption of NH_4-N from ammonium sulphate are given in Table II.

TABLE II

Absorption of nitrogen from ammonium sulphate
(NH_4-N figures in mg. per 100 gm. of soil)

NH_4-N supplied	NH_4-N not absorbed	NH_4-N absorbed	F by extrapolation
	Akola		
4	....	4	
40	....	40	
640	165·6	474·4	
1280	600·8	679·2	35·2
	Bantala		
4	....	4	
8	....	8	
40	1·6	38·4	
80	2·0	78·0	23
	Bargarh		
4	....	4	
8	....	8	
40	3·5	36·5	
80	17·4	62·6	25

TABLE II—(*contd.*)

Absorption of nitrogen from ammonium sulphate

(NH_4-N figures in mg. per 100 gm. of soil)

NH_4-N supplied	NH_4-N not absorbed	NH_4-N absorbed	F by extrapolation
	Bijapur		
4	....	4	
40	....	40	
640	254·6	385·4	
1280	743·2	536·8	96
	Kanpur		
4	....	4	
8	....	8	
40	9·6	30·4	
80	30·8	49·2	22
	Dacca		
2	3·5	—1·5	
4	2·8	1·2	
20	7·0	13·0	
40	19·6	20·3	9
	Delhi		
4	....	4	
20	....	20	
40	2·0	38·0	
80	4·5	45·5	32
	Guntur		
20	....	20	
40	....	40	
320	2·9	317·1	
640	29·3	610·7	300

TABLE II—(*contd.*)

Absorption of nitrogen from ammonium sulphate

(NH_4-N figures in mg. per 100 gm. of soil)

NH_4-N supplied	NH_4-N not absorbed	NH_4-N absorbed	F by extrapolation
	Guzranwala		
2	3·2	—1·2	
4	2·6	1·4	
20	5·2	14·8	
40	9·5	30·5	6
	Jharguda		
4	....	4	
8	....	8	
40	13·9	26·1	
80	42·5	37·5	20
	Jorhat		
4	3·5	0·5	
8	5·2	2·8	
40	24·8	15·2	
80	56·0	24·0	9
	Kalyanpur		
2	....	2	
4	....	4	
40	14·0	26·0	
80	41·1	38·9	19
	Peshawar		
2	1·4	0·6	
4	1·7	2·3	
40	10·7	29·3	
80	31·1	48·9	15

TABLE II—(*concld.*)

Absorption of nitrogen from ammonium sulphate

(NH_4-N figures in mg. per 100 gm. of soil)

NH_4-N supplied	NH_4-N not absorbed	NH_4-N absorbed	F by extrapolation
	Pusa		
2	0·4	1·6	
4	0·8	3·2	
20	6·8	13·2	
40	19·9	20·1	11
	Ranchi Upland		
4	....	4	
8	....	8	
40	14·9	25·1	
80	43·9	36·1	19
	Ranchi Valley		
4	....	4	
8	....	8	
40	1·5	38·5	
80	2·2	77·8	15
	Sambalpur		
4	....	4	
8	....	8	
40	1·3	38·7	
80	2·4	77·6	24
	Sialkot		
4	....	4	
8	....	8	
40	1·1	38·9	
80	5·5	74·5	30
	Waraseoni		
10	....	10	
20	....	20	
80	30·4	49·6	
160	95·6	64·4	43

GENERAL DISCUSSION

It is clear that the nitrogen fixing capacity of a soil as determined by the present method represents the maximum limit of nitrogen which when applied to a soil, will not be readily lost by leaching. Absorption of ammonium nitrogen from ammonium sulphate is generally believed to take place primarily by base exchange, a property common to both the organic and inorganic colloidal constituents of a

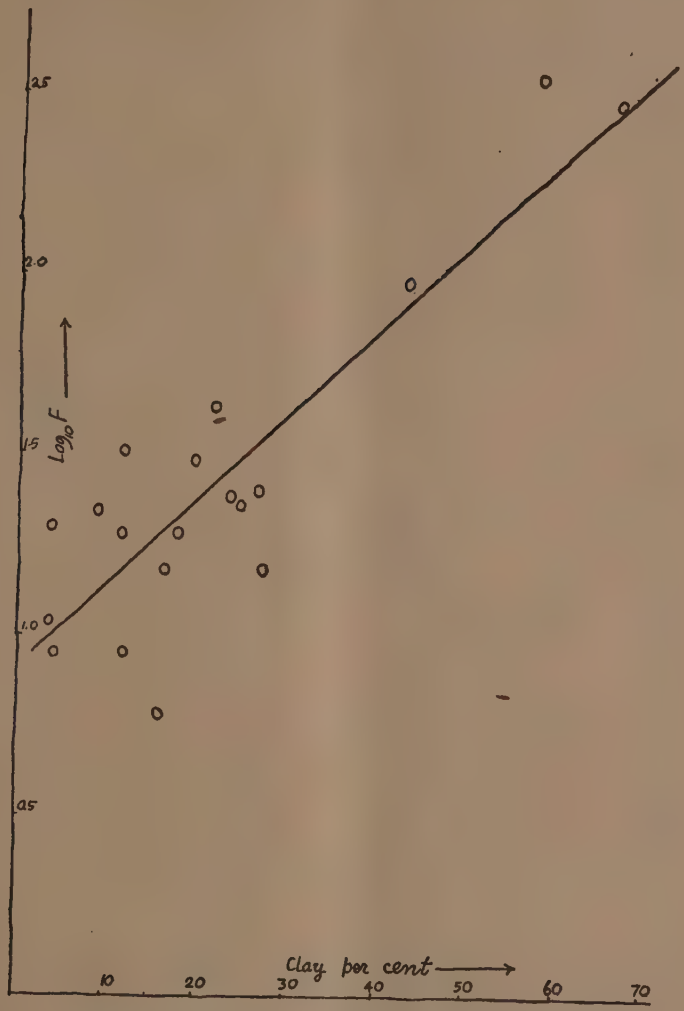

FIG. 2. Relationship between clay content and nitrogen fixing capacity of soils.

soil. The process may also be connected to a certain extent, to formation of organic insoluble ammonium complexes as suspected by Porges (*loc. cit.*). While the latter process is very difficult to be evaluated, the former can express itself in a series of correlations between the nitrogen fixing capacities and the soil characters exhibiting the property of base exchange. A correlation between the nitrogen fixing capacity and base exchange capacity is not, altogether unexpected. By subjecting the data

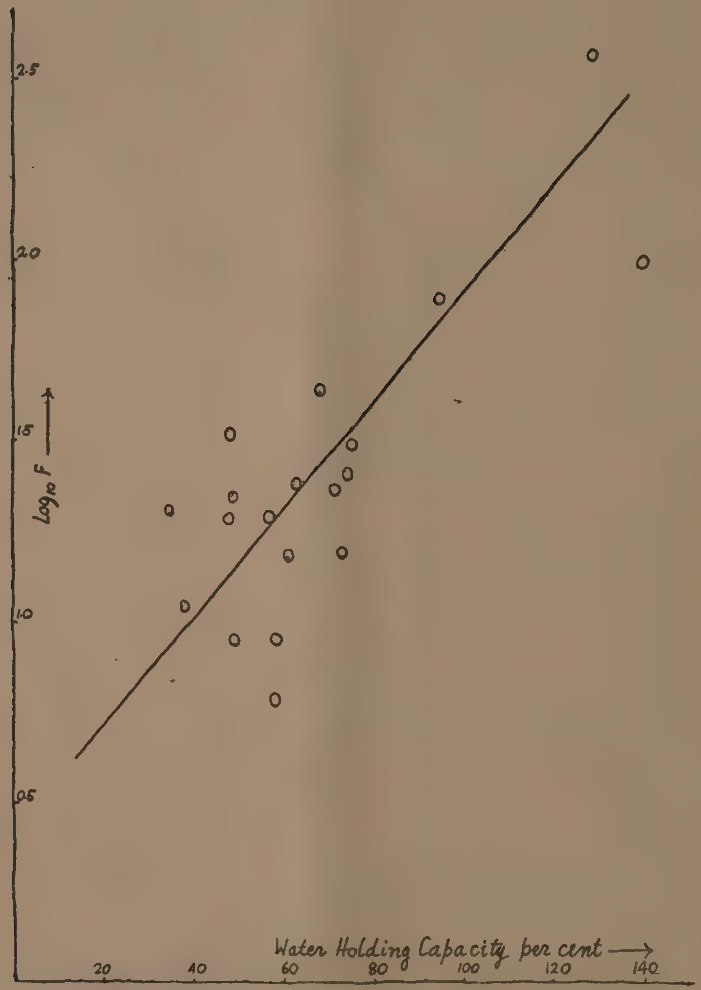

FIG. 3. Relationship between water holding capacity and nitrogen fixing capacity of soils.

to analysis by the method of least squares, it is observed that the correlation coefficient between the logarithm of F (base 10) and base exchange capacity is +0·8920. The relationship can be expressed by the equation $\log_{10} F = 0{\cdot}9569 + 0{\cdot}0258\ B$ (Fig. 4) where B is the base exchange capacity in milli-equivalents per 100 gm. of soil.

Similar relationship can be expected between the nitrogen fixing capacity and some other soil characteristics more or less connected with the phenomenon of base

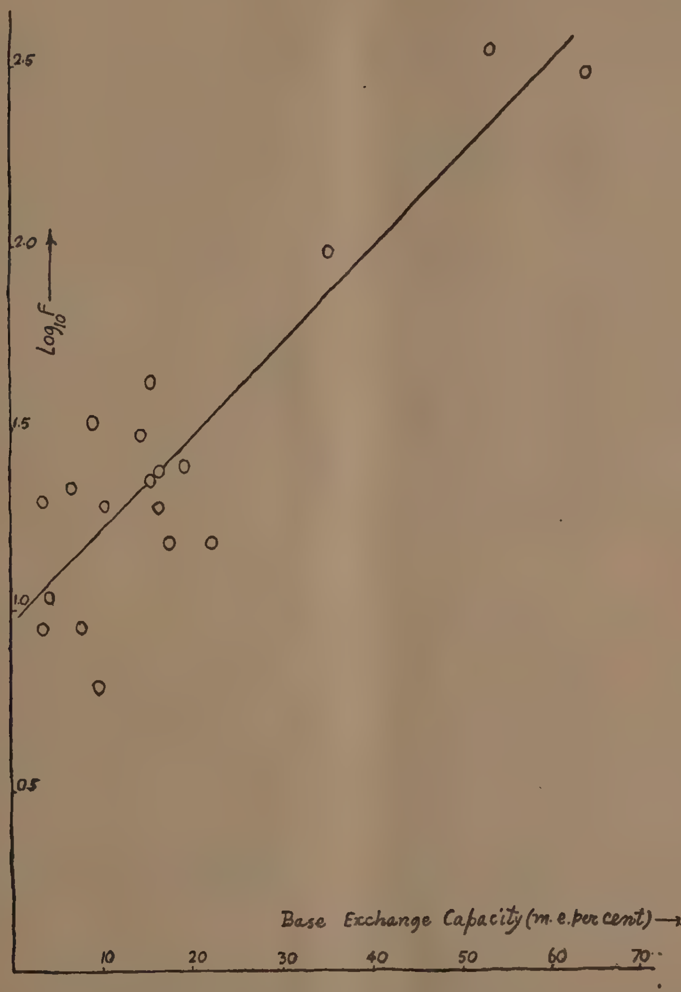

Fig. 4. Relationship between base exchange capacity and nitrogen fixing capacity of soils.

exchange. In Table III are given the correlation coefficients and the regression equations between the logarithm of F and these soil factors.

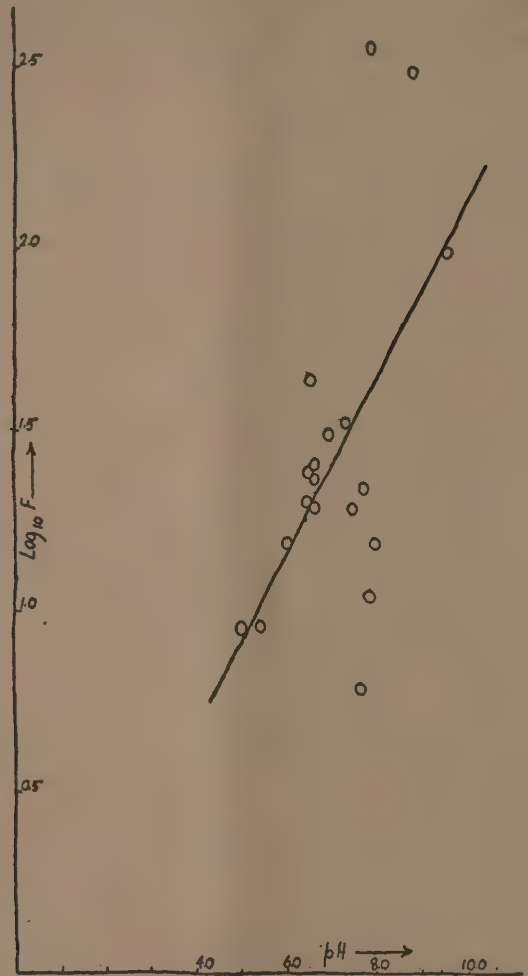

FIG. 5. Relation between *p*H and nitrogen fixing capacity of soils.

TABLE III

Correlation between the nitrogen fixing capacity (F), clay content (C), reaction (R) and water holding capacity (W) of the soils.

Variables	Correlation coefficient	Regression equation	Reference
$\log_{10}$ F and C	+0·8768	$\log_{10}$ F=0·9066+0·0236 C	Fig. 2
$\log_{10}$ F and R	+0·5781	$\log_{10}$ F=0·3149+0·2457 R	Fig. 3
$\log_{10}$ F and W	+0·8637	$\log_{10}$ F=0·4291+0·0147 W	Fig. 4

It is seen from Table III that there is a high correlation between $\log_{10}$ F and any one of the characters B, C and W. Also it is noticed that the correlation observed between any two of the factors B, C and W is of a very high order. None of the partial regression coefficients has come out to be significant and the multiple correlation between $\log_{10}$ F and B, C, W and R is found to be 0·8964. This shows that the simple regression equation between $\log_{10}$ F and any one of the characters B, C and W is good enough for the prediction of $\log_{10}$ F.

The increase in the nitrogen fixing capacity at a higher *p*H suggests that, in order to benefit by an application of ammonium sulphate, it is desirable that the *p*H of the solution or the soil should be adjusted to neutral if not slightly alkaline condition.

It is quite apparent that the nitrogen fixing capacities of soils exceed the usual amounts of nitrogen as ammonium sulphate applied to soils in actual fertiliser practices. One mg. of nitrogen per 100 gm. of soil is equivalent to 65 lb. of nitrogen per acre foot and on that basis, a soil having nitrogen fixing capacity of 10 mg. will be able to hold 650 lb. of nitrogen against leaching and loss with water. This moreover indicates, that an application of 100 lb. of nitrogen per acre is rather small as compared to the potential capacity of the soils to hold up ammonium nitrogen against losses by drainage. The real risk, therefore, lies in volatilisation of ammoniacal nitrogen as observed by earlier workers and unless the absorbed nitrogen is quickly nitrified and water soluble nitrates are formed, the usual applications of nitrogen to the soils in the form of ammonium sulphate may never be attended with the danger of being lost by drainage.

Summary and conclusions

Absorption of nitrogen from ammonium sulphate was studied in the case of 19 soils from different parts of India.

The method employed for the study consisted in adding to the soil, kept in percolators, required amounts of ammonium sulphate solution and allowing the mixture to act for 24 hours at a moisture content equivalent to half the water holding capacity of the soil. This treatment gave sufficient time for chemical and physical reactions of fixation or adsorption to take place but it was not long enough to allow the subsequent secondary changes by micro-organisms to affect the primary reaction. The unabsorbed free salt was afterwards removed by leaching with water. From the amounts of ammonium nitrogen added and that obtained in the water leachate, the amount of nitrogen absorbed by the soil could be calculated. It was observed that, when small quantities of ammonium nitrogen were added, the whole of the nitrogen was absorbed, there being no ammonium nitrogen in the water leachate. With increasing additions of ammonium nitrogen a part was absorbed and a part leached out with water. On plotting the amounts of nitrogen absorbed by the soil against those supplied to it, it was found that two straight lines could be obtained, one by joining the points when nitrogen supplied was wholly absorbed and the other by joining the points when nitrogen started leaching out in part. The point of intersection of the straight lines was termed F.

The point corresponded to the maximum amount of nitrogen, the soil was capable of absorbing and holding off against drainage or leaching with water and was termed the nitrogen fixing capacity.

The nitrogen fixing capacities of the soils were observed to increase with the increase in clay content, base exchange capacity, reaction and water holding capacity of the soils. Significant correlations were observed between nitrogen fixing capacities and these soil characters.

The usual applications of nitrogen to the soil in the form of ammonium sulphate appeared to be much below the values of nitrogen fixing capacities. It appeared, therefore, that the risk of losing nitrogen from applications of ammonium sulphate did not lie in loss by leaching.

ACKNOWLEDGEMENT

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APPENDIX I

Composition of the soils

(Constituents expressed as per cent on even dry basis)

Mechanical fractions			Soluble salts	Org. C	Org. N	*p*H	B.E.C. (m.e.)	Water holding capacity
Sands	Silt	Clay						
Akola—C. P., Heavy black cotton soil								
12·37	28·89	57·74	0·089	0·72	0·056	7·91	53·2	129
Bantala—Orissa, Light yellow laterite soil								
52·04	16·58	24·94	0·029	0·27	0·026	6·64	15·9	71
Bargarh—Orissa, Greyish black soil								
57·22	16·04	26·74	0·025	0·24	0·018	6·61	19·2	74
Bijapur—Bombay, Heavy black alkaline soil								
41·20	15·36	43·44	0·086	0·60	0·040	9·49	35·3	95
Kanpur—U. P., Greyish loam, alluvial soil								
71·98	19·14	8·88	0·074	0·48	0·073	7·69	6·9	49
Dacca—Bengal, Red loam, laterite soil								
60·00	28·22	11·78	0·081	0·70	0·070	4·97	7·4	58
Delhi—Delhi, Yellow light loam, alluvial soil								
77·24	11·18	11·58	0·055	0·32	0·040	7·30	9·2	48
Guntur—Madras, Heavy black soil								
23·10	10·24	66·66	0·051	0·77	0·054	8·83	63·4	140
Guzranwala—Punjab, Pink windborne soil								
62·50	21·78	15·72	0·096	0·49	0·089	7·57	9·9	56
Jharguda—Orissa, Yellow sandy laterite soil								
84·34	12·10	3·56	0·009	0·20	0·028	6·42	3·3	35
Jorhat—Assam, Yellow light alluvial soil								
82·80	13·24	3·96	0·067	0·73	0·072	5·43	3·1	49
Kalyanpur—U. P., Black alluvial soil								
70·22	18·68	11·10	0·071	0·35	0·046	7·42	10·2	48

APPENDIX I—(*contd.*)

Composition of the soils

(*Constituents expressed as per cent on oven dry basis*)

Mechanical fractions			Soluble salts	Org. C	Org. N	*p*H	B.E.C. (m.e.)	Water holding capacity
Sands	Silt	Clay						
			Peshawar—N. W. F. P., Pink alluvial loam					
44·92	37·94	16·14	0·090	0·73	0·064	7·90	17·5	61
			Pusa—Bihar, Greyish white calcareous loam					
63·04	33·08	3·08	0·065	0·59	0·064	7·82	4·2	38
			Ranchi Upland—Bihar, Reddish yellow loam					
68·88	13·24	17·88	0·026	0·39	0·042	6·60	16·6	57
			Ranchi Valley—Bihar, Yellow loam					
51·38	21·32	27·30	0·055	0·65	0·082	5·98	22·1	73
			Sambalpur—Orissa, Yellow loam					
65·48	11·00	23·52	0·022	0·25	0·022	6·52	16·4	63
			Sialkot—Punjab, Yellow alluvial loam					
26·38	53·82	19·80	0·056	0·56	0·078	6·86	14·3	75
			Waraseoni—C. P., Greyish black soil					
50·18	28·15	21·67	0·085	0·49	0·032	6·46	15·8	68

APPENDIX II

Ammonium nitrogen content of the soils

(*expressed as mg. per cent on oven dry basis*)

Soil	NH_4-N in NaCl extract	NH_4-N in water extract
Akola	3·4	0·9
Bantala	4·3	1·4
Bargarh	4·1	1·4
Bijapur	2·4	0·5
Kanpur	3·4	1·9
Dacca	9·1	3·2
Delhi	3·4	1·4
Guntur	2·9	1·4
Guzranwala	4·3	0·5
Jharguda	1·9	0·7
Jorhat	7·7	2·9
Kalyanpur	3·8	2·4
Peshawar	4·3	1·9
Pusa	3·6	1·4
Ranchi Upland	2·4	0·5
Ranchi Valley	4·8	1·4
Sambalpur	1·9	1·4
Sialkot	2·4	1·4
Waraseoni	5·2	2·4

STUDIES ON TILLAGE

II. EFFECT OF DEPTH OF CULTIVATION ON THE YIELD OF MAIZE AND WHEAT

By A. R. KHAN and B. P. MATHUR, Division of Agronomy, Indian Agricultural Research Institute, New Delhi

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IN the first article of the series [1953], the senior author discussed results of seedbed preparation, with alternative forms of tillage implements for wheat. The superiority of bullock-drawn implements over the tractor ones under normal cultivation practice was then established. The present investigation had to be undertaken with the object of obtaining experimental evidence on the mooted question of depth of cultivation, which ultimately reflects the cost, to arrive at some conclusion.

Many years ago deep ploughing was strongly advocated and several experiments were conducted in different parts of the world to determine the optimum depth of ploughing for wheat and other crops. Keen observed, ' Contrary to deeply ingrained tradition, crop yields are remarkably insensitive to variation in tillage '. II ' In Ui, a Russian investigator could not notice an increase in the yield of wheat due to deep ploughing. Bailey writes 'the depth of ploughing is a question of condition '.

Having the above-mentioned background in view this investigation was taken up in the *kharif*, 1949, on the main block 3F of the Indian Agricultural Research Institute farm at Delhi.

EXPERIMENTAL

The object of the experiment reported herein was to study the effect of depth of cultivation, with and without inversion, on the yield of maize and wheat in a 'maize-berseem-fallow-wheat rotation '. The details are as follows :

TREATMENTS

(*a*) *Main-plot*

C1—Ploughing 9-10 in. deep with tractor soil inversion plough in the first instance followed by normal cultivation with tractor implements, to achieve a suitable seed-bed for the two crops under experiments, (1) Maize in *kharif*, (2) wheat in *rabi*.

C2—Ploughing upto five inches depth with soil inverting plough drawn by bullocks, followed by normal cultivation with the local country plough.

C3—Ploughing upto 4-5 in. depth with the local country plough without inversion, throughout the season.

C4—Tractor discing to a depth of about four inches.

(*b*) *Sub-plot*

N_0—No manure.

N_1—Farm yard manure 40 lb. nitrogen per acre.

N_2—Farm yard manure 80 lb. nitrogen per acre.

N_3—Farm yard manure 120 lb. nitrogen per acre.

Layout. Split-plot design with 4×4 treatment combinations and 3 replications.

Rotation. Maize—berseem—fallow—wheat. Berseem and fallow were included to keep the land in good tone by maintaining a high standard of fertility. Soil used for the investigation was a sandy loam containing the following physical composition :

Soil separates	Percentages
Coarse sand	1·00
Fine sand	75·40
Silt	10·00
Clay	12·75

The land under trial was well drained, uniform in texture, and of average fertility with a *p*H of 7·9. Cultivations given to maize were about half of those for wheat which, in general, was tilled 5 or 6 times with tractor and nine times by bullock-drawn implements according to scheme.

It has been observed from the examination of tilth in wheat that aggregates of the size of 3·5-1 mm. contained the maximum amount of clay and a higher water stability than others. They were also capable of greater moisture retention. These aggregates were found more under C_3 (Country plough) and N_2 (80 lb. nitrogen per acre) treatments. Plots ploughed with 'country' showed two per cent increase in moisture over the tractor ones.

Results

Due to almost identical results the studies on this 'soil type' were closed after the completion of two cycles of rotation. The investigation was then shifted on a heavier type of land, where it is still in progress.

Results obtained from maize are given in Table I.

TABLE I

Yield in maunds per acre of maize grain

Treatments Cultural	1949 (manurial)					1950 (manurial)				
	N_0	N_1	N_2	N_3	Average	N_0	N_1	N_2	N_3	Average
C_1	25·34	25·51	24·90	34·67	25·11	20·66	24·25	23·90	24·49	23·33
C_2	20·16	21·50	22·45	25·06	22·30	14·97	16·60	18·34	20·19	17·52
C_3	21·56	21·72	17·93	22·56	20·94	15·90	19·73	17·06	23·44	19·03
C_4	23·00	19·88	21·83	21·44	21·54	20·19	20·66	19·50	24·37	21·17
Average	22·51	22·17	21·77	23·44		17 93	20·37	19·70	23·12	

'F' for main-plot treatments, sub-plot treatments and interaction not significant.		'F' for main-plot and interaction not significant 'F' for sub-plot highly significant.	
Main-plot—			
S. Em	$\pm 3{\cdot}29$	S. Em	$\pm 1{\cdot}63$
Sub-plot—			
S. Em	$\pm 1{\cdot}69$	S. Em	$\pm 1{\cdot}31$
		C. D. 5 per cent	2·65
Interaction S. Em	$\pm 3{\cdot}19$	S. Em	$\pm 1{\cdot}57$

It would appear from Table I that the differences between cultural treatments are not significant. The deep ploughing treatment gave a lead over the rest. In the case of sub-plot the differences between 'blank' and manurial treatments, even with as high a dose of nitrogen as 120 lb. per acre, are almost *nil* in the first year. During the second cycle the difference between the 'blank' and highest dose of manure is, though, significant but not so with others. This shows the dynamic effect of rotation where a vigorous clover like berseem (*Trifolium alexandrinum*), when preceded and afterwards included in the rotation, practically masked the effect of manures. This is a very important consideration as clover should provide most of the vast amount of protein needed by the large livestock population of the country and at the same time fix atmospheric nitrogen for soil enrichment. In other experiments, with berseem in rotation, the senior author [1952] has obtained results in line with those just discussed.

TABLE II

Yield in maunds per acre of wheat grains

Treatments Cultural	1949-50 (manurial)					1950-51 (manurial)				
	N_0	N_1	N_2	N_3	Average	N_0	N_1	N_2	N_3	Average
C_1	25·53	23·02	25·07	31·57	26·29	34·44	38·44	37·14	39·74	37·44
C_2	28·80	35·09	30·73	35·09	32·45	36·21	40·11	42·06	41·50	39·97
C_3	38·81	34·72	34·54	27·95	34·00	36·49	40·48	38·81	44·93	40·23
C_4	27·29	34·11	36·58	33·80	32·99	35·28	37·88	38·06	37·41	37·16
Average	30·13	31·75	31·72	32·12		35·64	39·23	39·02	40·90	

	'F' for main-plot treatments, sub-plot treatments and interaction not significant.	'F' for main-plot treatments and interaction not significant. 'F' for sub-plot treatments highly significant.
Main-plot—		
S. Em	±2·77	±1·18
Sub-plot—		
S. Em	±2·29	±0·60
C. D. at 5 per cent		1·73
Interaction S. Em	±4·62	±1·19

The cultural differences are, again, not significant. Contrary to maize, the lead in wheat has been taken by C_3 (country plough) treatment. The yields are remarkably indifferent to the variation in the depth of ploughing.

It will be noted that fairly high yields of wheat were produced on 'check' plots and those receiving the higher manure applications. This may be due to the fact that wheat was grown after fallow and 'berseem'. The favourable influence of a decidedly better clover supplemented by 'fallowing' helped push forward the yields of wheat thereby eliminating the use of manures under such a system of cropping.

Discussion

The most important point brought out from the study in the case of both maize and wheat is that, deep ploughing under these conditions is not necessary. A small increase in a rainfed crop of maize was noticed because of greater storage of water in the soil. King [1892] and Grandean [1894] confirm this view. Begachak [1938], Kuran [1948] and Ivanov [1950] also noted an increase in the amount of reserve moisture due to deep ploughing in the root layer of soil. In the case of irrigated wheat, however, highest yield was consistently obtained with shallow ploughing.

Additional confirmatory evidence in favour of shallow ploughing has been obtained from various workers all over the world. William and Welton [1915] comparing yields of maize, wheat and other crops found no difference in favour of deep ploughing or sub-soiling. Miller [1916] at Kansas Experimental Station did not notice any difference between 3 inch and 12 inch depths of ploughing on the yield of maize and wheat. Chilcott and Cole [1918] did not find deep ploughing efficient for corn and wheat. Russell and Keen [1934] at Rothemsted, found no difference between 4 and 8 inches depth of cultivation.

The work done by a large number of workers including Sewell and Call [1920] Torstensson [1943], Doneen [1947] and Russell [1950] also shows no such differences between deep and shallow ploughing.

With the recent advances in soil science it is becoming increasingly clear that good physical conditions of soil is as, if not more, important as its chemical constitution. The combined effect of physico-chemical and biological activities of soil.

stimulated by suitable adjustment of air and moisture renders an easy flow of nutrition to the plants, as is reflected on the yield of crops. The structural pattern of seedbed or 'tilth' was the best under 'shallow' cultivation with country plough. This may, perhaps, be the cause of highest yield in wheat obtained under this treatment. Discing, however, did not produce the same effect due to great pulverisation of soil, making it fluffy and single-grained, which is not conducive to good yields.

Another important incidental observation was on the role of rotation which was so dynamic as to eclipse the effect of added manure in crop production. In any programme of fertility building of our land this would, it is hoped, receive due attention.

Summary and conclusion

The inference to be drawn from this study is :

(1) Ploughing deeper than five inches is not advantageous.

(2) On lands free from weeds, the effect of inversion is not marked.

(3) Too fine stirring of soil, as effected by discing, is not desired.

(4) The time-honoured implement—country plough—is still a good stabiliser of yield.

(5) There is no obvious advantage in heavy manuring under maize-berseem-fallow-wheat rotation.

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EVOLUTION OF COLOUR PATTERN IN *COCCINELLA SEPTUMPUNCTATA* LINN., VAR. *DIVARICATA* OLIV.

By B. K. Varma, M. Sc. (Agri.), Research Fellow, Section of the Entomologist to Government, U. P., Kanpur

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(With two text-figures)

THE study of the progressive, individual variations in the colour pattern of insect species is of great taxonomic value. Johnson [1910], Sturtevant, Galvin and Park [1952] are some of the workers who have dealt with the elytral variations in lady beetles. In specimens of *Coccinella septumpunctata* Linn., collected at Kanpur during 1945-50, marked variations in the colour pattern were observed. A series of specimens intergrading the species *C. septumpunctata* with its variety *divaricata* Oliv., were traced and are illustrated in Fig. 2. The reason for linking the variates (b-i) with (*a*) is the apparent continuous variation exhibited by the elytral patterns of the former group towards definite direction which proves their common descent from the latter. Along with specimens thus related are two other non-related specimens (c, d) which refer to aberrant specimens of the variety *divaricata* of *C. septumpunctata*. The pronotal colour patterns of these specimens, strangely enough, show slight variations only in size and not at all in design and, therefore, little importance can be attached to them. The variety *divaricata* Oliv. and the intermediate specimens shown in Fig. 2, other than *C. septumpunctata* are very rare and their percentages out of a collection of 1,072 beetles are given in Table I.

Table I

Percentage of variates in 1,072 specimens of C. septumpunctata *adults*

Type of variate	a	b	c	d	e	f	g	h	i	j	k
Number	690	172	8	6	38	12	10	4	95	26	11
Percentage	64·8	16·0	0·7	0·5	3·5	1·1	0·9	0·3	8·8	2·4	1

In a typical specimen of *C. septumpunctata* the pronotum (Fig. 1) is black except for a small sub-quadrate or sometimes re-entrant area on the cephalolateral angles which are yellowish orange in colour. The ground colour of the elytra (Fig. 2a) is orange yellow to crimson red in colour, ornamented by seven black round spots.

The half of the first elytral spot is situated mid-suturally below the pronotum, the second and fourth spots are situated on the linea externa running parallel to the costal margin and the third spot is on the linea interna slightly above the anterior half of the elytra but lower than the second spot.

Comparative descriptions of the elytral colour variations in some forms intermediate between *C. septumpunctata* described above and its variety *divaricata* Oliv., are as follows, the elytral spots being counted antero-posteriorly.

In form b (Fig. 2) the first spot extends caudad into a fine streak towards the third spot and appears spindle shaped. The second spot is hastate, prolonged caudad mucronately along the reflexed costal margin towards the fourth spot. The fourth spot is large in size and the enlargement is particularly more in the direction of the second spot. In forms c and d (Fig. 2) the first spot is lengthened caudad in the former and unchanged in the latter. The third and fourth spots in form c, are enlarged caudad and laterad respectively and coalesce somewhat at right angles but in form d, apart from the general enlargement of the spots, the second and third spots are extended transversely towards the linea media and coalesce truncately giving rise to a band. These two specimens though related to *C. septumpunctata* are in no way correlated because of their tendency to develop a seemingly different colour pattern which also separates them from other intermediate forms.

In the form e (Fig. 2) the second and fourth spots are joined through a thread-like black line and the third spot is prolonged cephalolatered towards the second spot.

Yet, another form f (Fig. 2) shows a general enlargement of all the spots, the third and the fourth spots are spread in the direction of the elytral suture, the former encroaches towards the second spot laterally and the latter towards the third spot dorsally. The inter-connecting line of the second and fourth spots is thick towards the side of the former.

In the form g (Fig. 2) the fourth spot coalesces with the third through a thick line, the latter spreads along its longest length towards the middle of the elytra and is more near to the cephalic end of the second spot.

In the form h (Fig. 2) the third spot is coalesced with the second spot through a broad band and the line inter-connecting the fourth spot with the third is thicker. The distribution of the ground orange coloured area of the elytra in this form is in the following manner.

There is a broad basal area which is contiguous with a narrow sutural margin on the left and a narrow apical margin along with an elongate costal margin on the right. An oval orange area is in the middle of the elytra.

Lastly in the form i (Fig. 2) which is also the variety *divaricata*, the black pigmented area extends up to the first spot, leaving only the posterior sutural margin of the elytra orange coloured. The middle orange area is reduced to a crescent shape due to the spreading of the black pigment from the side of the original third and second spot and from the side of the fourth spot towards the middle of the elytra. The basal orange coloured area is elliptical in shape whose posterior margin

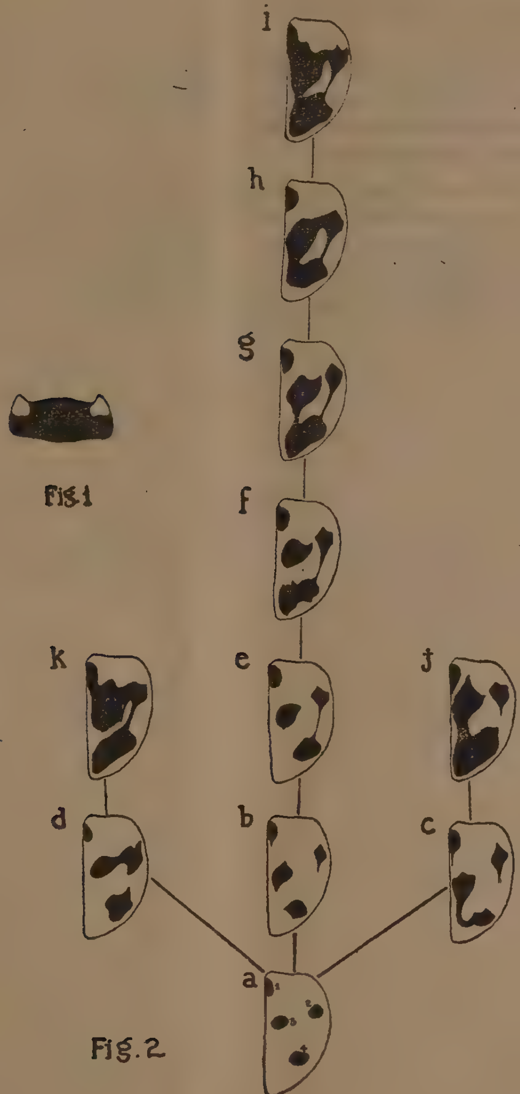

Fig.1

Fig.2

Fig. 1. Pronotum of *Coccinella septumpunctata* Linn.
Fig. 2. a. Elytra of *Coccinella septumpunctata* Linn.
i. Elytra of *Coccinella septumpunctata* Linn. var. *divaricata* Oliv.
b, c, d, e, f, g, h, j, k, Elytra of the variates

is emarginated and is contiguous up to the narrow apical margin through an elongate costal margin.

In the forms j and k (Fig. 2) the former is linked with the form c, because of the further enlargement of the third and fourth spots and the thickening of the band joining them. Similar is the reason of associating the form k with d, where the spots third and fourth are unjoined.

From the above description it is clear that the coalescing of the spots in *C. septumpunctata* is by the gradual spreading of the black pigmented area along certain well defined lines. What is more interesting is the condition exhibited by the elytral colour patterns of the intermediate forms intergrading *C. septumpunctata* with its variety *divaricata*, following a rigid variational direction.

Acknowledgment

I am thankful to Dr K. B. Lal, Entomologist to Government, U. P., in whose laboratory the work was carried out, for help and facilities.

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FURTHER STUDIES ON THE COLD STORAGE OF MANGOES

By K. KIRPAL SINGH, N. S. KAPUR and P. B. MATHUR, Central Food Technological Research Institute, Mysore

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(With two text-figures)

MANGO (*Mangifera indica*) is the most important fruit of India and one of the most delicious fruits of the world. In 1948-49, the total area under mango in the Indian Republic was 22,12,852 acres [Lal, Tandon and Pruthi, 1952]. The mango is grown practically in all the States in the Indian Republic. Uttar Pradesh, with 13,22,656 acres, produces by far the largest quantity of mangoes in India, [Lal, Tandon and Pruthi, 1952].

As in other fruits and vegetables, the stage of maturity at the time of cold storage is of considerable importance in the case of mango also. Cheema and Dani [1934] have defined four stages of maturity in Alphonso mango: (1) 'A' stage. The shoulders are in line with the stem end and the colour of the fruit is oil green. (2) 'B' stage. The shoulders outgrow the stem end and the colour is oil green (3) 'C' stage. The shoulders outgrow the stem end and the colour lightens, and (4) 'D' stage. The flesh becomes soft and the blush develops. Wardlaw and Leonard [1936] have described three stages during the growth and development of the Julie variety of mangoes: (1) Almost full grown, green fruits in which the shoulders are in level with the insertion of the stem end, (2) a later stage where further growth has taken place so that the shoulders are raised above the hollow in which the stem end is inserted, and (3) a stage where little or no growth has taken place, but the fruits are on the point of becoming soft.

With regard to the optimum temperature for the cold storage of mangoes Cheema, Karmarkar and Joshi [1950] have come to the following conclusions: (1) Green fruit of 'B' stage of maturity is chilled at temperatures below 45°F. and (2) 48°F is the optimum temperature for the cold storage of mangoes. According to Wardlaw and Leonard [1936] the optimum temperature for mango storage is 45°F. Mathur, Singh and Kapur [1952] have come to the following conclusions with regard to the cold storage of mangoes: (1) Mysore-grown seedling mangoes can be stored for 42 days at 42-45°F. (R. H. 85-90 per cent) in a green condition (2) Mysore-grown Raspuri (Peter) mangoes can be stored for a maximum period of 42 days at 42-45°F. (R.H., 85-90 per cent) in a green condition and (3) Mysore-grown Badami (Alphonso) mangoes can be stored for a maximum period of 28 days in a good condition at a temperature of 47-50°F. (R. H. 85-90 per cent).

Further, Singh and Mathur [1952] have recommended a temperature of 67-70°F. as the optimum for the ripening of mangoes. Singh, Sheshagiri and Gupta (1937), working with Krishnabhog and Langra varieties of mango, observed that there was a climacteric rise in the respiration rate with the commencement of ripening. Karmarkar and Joshi [1942] found that the respiratory activity of the green fruit

('B' stage of maturity) stored at 68°F. increased gradually, reached a peak value (climacteric) and then decreased during ripening.

MATERIAL AND METHODS

The fruit (variety Totapuri or Bangalora) was picked from a single tree in a private orchard in Mysore, on 27-5-52. Fully-grown but unripe fruits [corresponding to stage 'B' of Cheema and Dani, 1934] were selected and stored in crates at the following temperature ranges : 35-38°F. (R.H. 85-90 per cent), 39-42°F. (R.H. 85-90 per cent), 42-45°F. (R.H. 85-90 per cent), 47-50°F. (R. H. 85-90 per cent), 52-55°F. (R.H. 85-90 per cent), 67-70°F. (R. H. 70-85 per cent) and room temperature, 73-85°F. (R. H. 50-75 per cent). A description of the cold storage chambers at this Institute has already been published by Mathur and Singh [1952].

The physiological losses in weight, i.e. losses due to transpiration and respiration were determined on six marked fruits at each temperature range, the same fruits being used to determine these losses throughout the period of investigation. For the estimation of percentage wastage due to low temperature injury and fungous diseases, 25 fruits were used at each temperature range. Another lot of 25 fruits was stored at each temperature range for drawing samples for the estimation of total soluble solids, acidity and ascorbic acid. Three fruits were drawn at 14-day intervals from these last-mentioned lots and made into a composite sample for the estimation of the chemical constituents mentioned above. For the measurement of respiration one fruit was marked at each temperature range, the same fruit being used for this measurement throughout the period of investigation. All these lots of fruits were stored in experimental crates (12 in. ×12 in.× 8 in.) provided with slits for adequate ventilation. No wraps were used for the fruits.

The total soluble solids were determined by means of a hand refractometer. For the determination of total acidity, 10 gm. of the edible portion were macerated in a blender with distilled water and filtered. The filtrate was titrated against N/10 NaOH. For the estimation of ascorbic acid, 10 gm. of the edible portion were macerated in a blender and filtered. The filtrate was titrated against a standard solution of 2 : 6 dichlorophenol indophenol. The respiration measurements were made by the continuous current method. The CO_2 given off was absorbed in N/10 Barium hydroxide solution which was titrated against N/10 HCl at the end of the experiment.

Respiration rates were determined at 67-70°F. Fruits were transferred from the storage temperatures to the respiration chamber directly without any loss of time.

Estimations of total soluble solids (mainly sugars) and acidity are important from the point of view of quality of the fruit, because the taste of the ripened fruit depends to a large extent on the ratio of sugars to acids. Ascorbic acid (vitamin C) content determines the nutritive value of the fruit.

The practice of holding fresh fruits and vegetables in cold storage is based on the fact that a lowering of temperature depresses respiratory activity and thus retards the deterioration of the produce. The temperature at which the respiration rate is the lowest and the 'climacteric' occurs after the longest period in storage,

without the occurrence of low temperature injury, is the optimum temperature. Measurements of respiration are, therefore, important as additional pointers, together with other observations, towards the correct optimum temperature. Further, they are important from the point of view of research on the refrigerated gas-storage of fruits, since gas stores have to be sealed before the 'climacteric' occurs in order to obtain the maximum production of the CO_2 from the fruit.

Observations in regard to the ripening of fruits at the higher temperatures after storage for six and seven weeks at 39-42°F. and 42-45°F., were also made.

Data and discussion

The cumulative physiological losses in weight in mangoes stored at various temperatures are provided in Table I. The physiological losses in weight were found to be the least at 35-38°F followed by 42-45°F.

Table I

Cumulative physiological losses in weight in Totapuri mangoes stored at various temperatures

Storage temperature °F.	Original weight in gm (6 fruits)	Loss in weight after, weeks							
		1	2	3	4	5	6	7	8
35-38	1863·0	0·7	1·3	1·9	2·5	3·3	4·6	6·0	7·0
39-42	1955·0	1·5	2·8	4·0	5·4	6·6	7·7	8·9	10·4
42-45	1794·0	1·1	2·0	2·8	3·5	4·6	5·4	6·2	7·1
47-50	2054·0	1·2	2·9	3·8	4·7	5·9	6·9	8·2	9·5
52-55	2210·0	1·8	2·9	4·5	5·8	6·9	..	..	..
67-70	2062·0	4·6	8·9	13·9	..	..	..	..	..
R. T. (73-85)	2131·0	5·7	11·1	..	..	..	..	..	..

The data regarding the percentages of wastage due to low temperature injury and fungous diseases are presented in Table II.

Table II

Percentages of wastage due to low temperature injury and fungous diseases in Totapuri mangoes stored at various temperatures

Storage temperature °F.	Original number of fruits	Percentage of wastage after, weeks							
		1	2	3	4	5	6	7	8
35-38	25	0	0	0	0	0	40	60	100
39-42	25	0	0	0	0	0	4	40	100
42-45	25	0	0	0	4	8	8	8	28
47-50	25	0	0	0	0	8	32	80	88
52-55	25	4	4	8	44	56	76	..	..
67-70	25	0	8	16	..	..	..	..	..
R. T. (73-85)	25	12	24	..	..	..	..	..	..

It is obvious from Table II that from the point of view of least wastage, 42-45°F. is the most suitable temperature range for the cold storage of Totapuri mangoes. It should be noted, however, that no low temperature injury occurred above 42°F. in Totapuri mangoes.

TABLE III

Changes in percentage total soluble solids contents in Totapuri mangoes stored at various temperatures

Storage temperature °F.	Initial value	Total soluble solids contents after, 14-day periods			
		1	2	3	4
35-38	10·5	9·0	10·5	9·5	10·0
39-42	10·5	9·0	11·0	10·5	15·0
42-45	10·5	10·0	9·0	13·0	13·0
47-50	10·5	11·0	14·0	14·0	12·0
52-55	10·5	15·0	13·5	11·0	..
67-70	10·5	16·0	..	..	..
R. T. (73-85)	10·5	13·5	..	..	..

The data concerning the changes in percentage total soluble solids in mangoes stored at various temperatures are presented in Table III. At 35-38°F. the percentage of total soluble solids in mangoes remained practically the same throughout the eight weeks storage period. At 39-42°F. and 42-45°F. there was an increase in the percentage of total soluble solids in mangoes stored for a period of eight weeks. At all the other higher temperatures there was an increase in the percentage of total soluble solids followed by a decrease.

TABLE IV

Changes in percentage total acidity (in terms of malic acid) in Totapuri mangoes stored at various temperatures

Storage temperature °F.	Initial value	Percentage acidity after, 14-day periods			
		1	2	3	4
35-38	2·3	2·2	2·0	1·8	1·7
39-42	2·3	2·3	1·9	1·9	1·9
42-45	2·3	2·2	1·8	1·8	1·6
47-50	2·3	2·1	1·7	1·7	0·8
52-55	2·3	1·9	1·3	0·7	..
67-70	2·3	0·4	..	..	..
R.T. (73-85)	2·3	0·1	..	..	..

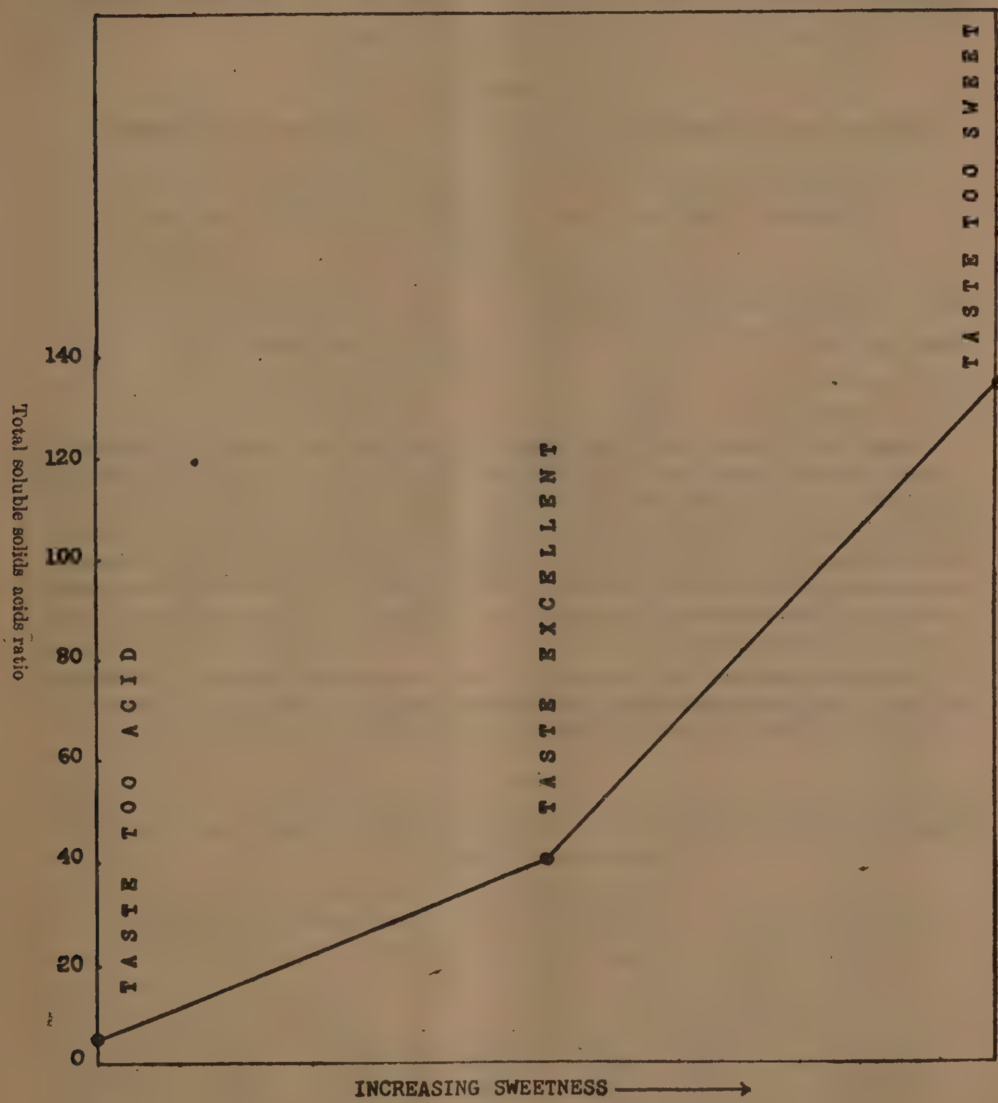

Fig. 1. Relation between total soluble solids/acids ratios and the taste of the fruit

The data regarding the changes in total acidity (in terms of malic acid) in mangoes stored at various temperatures are presented in Table IV. Generally speaking, there was a decrease in total acidity at all the temperature ranges investigated, the decreases being greater at the higher temperature ranges.

TABLE V

Relation between total soluble solids/acids ratios and the taste of the mangoes

Description of the fruit	T.S.S. / Acids	Taste of the fruit
Green fruits, prior to commencement of storage	4·6	Taste too acid
Fruits ripened at 67-70°F	40·0	Taste excellent
Fruits ripened at 73-85°F	135·0	Taste too sweet

Total soluble solids/acids ratios have been used in citrus fruits to judge their quality. Similar ratios were also calculated for Totapuri mangoes. In order to correlate these ratios with the taste of the mangoes, work was confined to three stages of the fruit, namely, (1) green fruits, prior to commencement of storage, (2) fruits ripened at 67-70°F. and (3) fruits ripened at 73-85°F. The data obtained are recorded in Table V and graphically shown in Fig. 1. It is obvious from these data that a total soluble solids/acids ratio of 40 indicates a properly ripened fruit in the case of this variety.

The data pertaining to the changes in the ascorbic acid contents in mangoes stored at various temperatures are presented in Table VI. The maximum retention of ascorbic acid was observed at 39-42°F. and 42-45°F.

TABLE VI

Changes in ascorbic acid contents in Totapuri mangoes stored at various temperatures

(In mg. per 100 gm. edible portion)

Storage temperature °F.	Initial value	Ascorbic acid contents after, 14-day periods			
		1	2	3	4
35-38	46·6	42·6	40·1	22·0	2·8
39-42	46·6	46·6	46·5	45·0	44·1
42-45	46·6	46·2	44·2	43·2	42·6
47-50	46·6	44·1	40·1	39·1	38·2
52-55	46·6	38·2	38·5	38·2	..
67-70	46·6	30·9	..	..	..
R. T. (73-85)	46·6	17·6	..	..	..

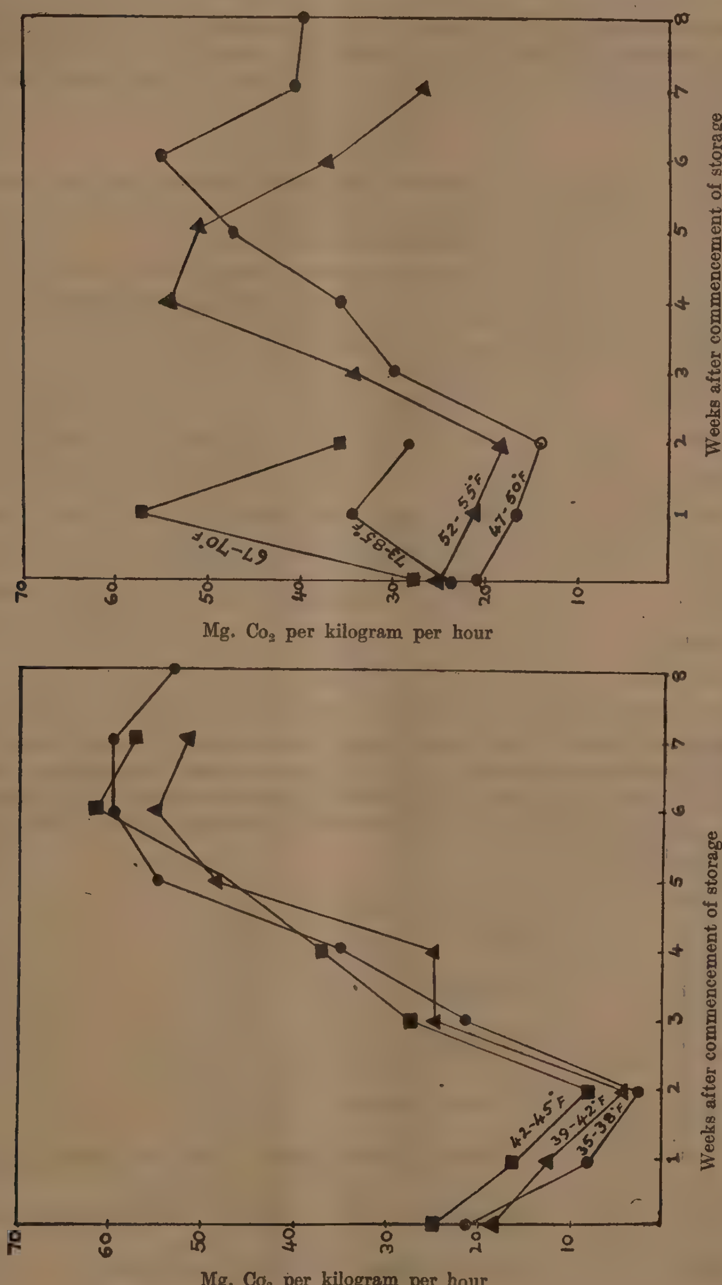

Fig 2. Resperation rates of Totapuri mangoes stored at various temperatures as determined at 67·78°F.

The data concerning the respiration rates of mangoes stored at various temperatures are presented in Table VII and graphically shown in Fig. 2. The respiration measurements were made at 67-70°F. In every case, the climacteric rise, followed by a fall, is evident.

TABLE VII

Respiration rates of Totapuri mangoes stored at various temperatures as determined at 67-70°F.

(In mg. CO2 per Kgm. per hour)

Storage temperature °F.	Initial value	Respiration rates after, weeks							
		1	2	3	4	5	6	7	8
35-38	21·9	8·1	2·7	21·5	35·1	55·1	60·2	60·2	53·9
39-42	18·9	12·2	4·0	24·8	25·2	49·4	55·5	52·7	..
42-45	24·7	15·9	8·1	27·8	37·4	48·3	61·8	57·9	46·3
47-50	20·8	16·8	13·7	29·9	35·4	47·9	55·3	40·9	40·0
52-55	25·2	21·4	18·3	34·2	54·2	51·4	36·8	26·9	..
67-70	26·7	57·5	35·9	..	..	..	..	..	..
R.T. (73-85)	24·9	34·4	28·3	..	..	..	..	..	..

During the course of this investigation, observations in regard to the external condition of the mangoes stored at various temperatures were made. In making these records, whenever most of the fruits in lot were found in an unmarketable condition due to rotting, further observations were discontinued. The results are summarised below:

After one week

35-38°F . . No visible change.

39-42°F . . No visible change.

42-45°F . . No visible change.

47-50°F . . No visible change.

52-55°F . . No visible change in sound fruits, one fruit rotting.

67-70°F . . Fruits getting soft. Change in colour from green to yellow.

73-85°F . . Fruits ripening, a few fruits have rotted.

After two weeks

35-38°F . .	A few fruits showing slight pitting due to low temperature injury.
39-42°F . .	No visible change.
42-45°F . .	No visible change.
47-50°F . .	Slight change in colour from green to yellow in some fruits.
52-55°F . .	Some fruits getting soft. Change in colour from green to yellow.
67-70°F . .	Most of the fruits have ripened with the development of characteristic yellowish-red colour, two fruits rotting.
73-85°F . .	Some fruits have ripened with the development of yellow colour, some more fruits have rotted.

After three weeks

35-38°F . .	Pitting due to low temperature injury has increased. A few fruits oozing out sap through stem ends.
39-42°F . .	No visible change.
42-45°F . .	No visible change.
47-50°F . .	Fruits getting soft. Change in colour from green to yellow.
52-55°F . .	A number of fruits have ripened with the development of yellow colour, one more fruit rotting.
67-70°F . .	Most of the fruits have ripened with the development of yellowish-red colour, a few fruits rotting.
73-85°F . .	All the sound fruits have ripened with the development of yellow colour.

After four weeks

35-38°F . .	Most of the fruits showing signs of low temperature injury. A few fruits oozing out sap.
39-42°F . .	No visible change.
42-45°F . .	No visible change, one fruit rotting.
47-50°F . .	Fruits getting soft. Change in colour from green to yellow.
52-55°F . .	Most of the fruits have turned soft with the development of yellow colour, some fruits rotting.

After five weeks

35-38°F . .	Fruits showing low temperature injury. A few fruits oozing out sap.
39-42°F . .	No visible change.
42-45°F . .	No visible change in sound fruits, one more fruit rotting.
47-50°F . .	Some fruits ripening, two fruits have rotted.
52-55°F . .	Some fruits have ripened, some more fruits rotting.

After six weeks

35-38°F . .	Ten fruits unmarketable because of low temperature injury.
39-42°F . .	No visible change in sound fruits, only one fruit rotting.
42-45°F . .	No visible change in sound fruits.
47-50°F . .	Fruits getting soft. Change in colour from green to yellow. A few fruits rotting.
52-55°F . .	Most of the fruits found rotting.

After seven weeks

35-38°F . .	Some more fruits have become unmarketable due to low temperature injury.
39-42°F . .	No visible change in sound fruits, 10 fruits showing spot rots and low temperature injury.
42-45°F . .	No visible change in sound fruits.
47-50°F . .	Most of the fruits found rotting.

After eight weeks

35-38°F . .	All fruits have developed brown patches (L.T.I.) and unmarketable.
39-42°F . .	All fruits unmarketable.
42-45°F .	No visible change in sound fruits, some more fruits have rotted.
47-50°F . .	Almost all fruits rotting.

Observations in regard to the ripening of fruits after a storage of six and seven weeks at 39-42°F and 42-45°F. showed that 42-45°F. is the optimum storage temperature from the point of view of subsequent ripening at 67-70°F. and the room temperature (73-85°F). The details of these observations are presented in Table VIII.

TABLE VIII

Details regarding ripening at 67-70°F. and 73-85°F. in Totapuri mangoes stored at 39-42°F. and 42-45°F.

Storage temperature °F.	Period of storage in weeks	Condition with regard to ripening			
		After 7 days at		After 14 days at	
		67-70°F	73-85°F	67-70°F	73-85°F
39-42	6	Fruits developed brown patches (L. T. I.) and started to rot	Fruits developed brown patches (L. T. I.) and started to rot	..	..
42-45	6	Fruits slightly under ripe	Some fruits nearly ripe	Fruits fully ripe	Fruits fully ripe
39-42	7	Fruits developed brown patches (L. T. I.) and started to rot	Fruits developed brown patches (L. T. I.) and started to rot	..	
42-45	7	Fruits slightly under ripe	Some fruits nearly ripe	Fruits fully ripe	Fruits fully ripe

SUMMARY

In the present investigation, Totapuri mangoes belonging to the 'B' stage of maturity were stored at the following temperature ranges: 35-38°F. (R.H. 85-90 per cent), 39-42°F. (R.H. 85-90 per cent), 42-45°F. (R.H. 85-90 per cent), 47-50°F. (R.H. 85-90 per cent), 52-55°F. (R.H. 85-90 per cent), 67-70°F. (R.H. 70-85 per cent) and room temperature, 73-85°F. (R.H. 50-75 per cent).

The following conclusions have been arrived at:

(1) The physiological losses in weight were found to be the least at 35-38°F. followed by 42-45°F.

(2) From the point of view of least wastage due to low temperature injury and fungous diseases, 42-45°F. is the most suitable temperature range for the cold storage of Totapuri mangoes.

(3) With the exception of 35-38°F., there was an increase in the percentage of total soluble solids in Totapuri mangoes stored at various temperatures.

(4) Generally speaking, there was a decrease in total acidity in mangoes stored at various temperatures, the decreases being greater at the higher temperature ranges.

(5) The maximum retention of ascorbic acid was observed in Totapuri mangoes stored at 39-42°F. and 42-45°F.

(6) Respiration measurements at 67-70°F. of mangoes stored at various temperatures showed that in every case the respiration rate attained a peak value (climacteric) and thereafter declined.

(7) The optimum conditions for the cold storage of Totapuri mangoes are a temperature of 42-45°F. and a R.H. of 85-90 per cent. The storage life at 42-45°F. was found to be seven weeks and the mangoes thus stored could be ripened either at 67-70°F. or room temperature (73-85°F). The ripening of mangoes at 67-70°F., however, yielded better results.

Acknowledgment

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A NOTE ON THE COLD STORAGE OF SAPOTAS (*ACHRAS SAPOTA*)

By K. Kirpal Singh and P. B. Mathur, Central Food Technological Research Institute, Mysore

(Received for publication on 9 November 1953)

SAPOTA, sapodilla, dilly or chico is of Tropical American origin. According to Wardlaw [1937], sapotas, exported from Java to Holland at a temperature of 37·4°F. arrived in a fairly good condition. On removal from cold storage, however, the fruits did not ripen well. Smith [1936] was able to store fully grown but unripe sapotas for a period of 16 days at 45°F. On removal to higher temperatures (80-93°F.) the fruit ripened in the course of 2-3 days to a product of good flavour. Comparable experiments conducted in Trinidad [Wardlaw, 1937] gave less favourable results. Gonzalez [1931-32] working with sapotas grown in Philippine Islands concluded that full-grown green fruits stored at 32°F. for five days could be ripened satisfactorily at the room temperature (85°F). Moreover, it was found that eating ripe fruit could be stored at 32°F. for two weeks in an excellent condition. According to Campo [1934-35] the cold storage life of Philippine-grown sapotas depends on the stage of maturity at the time of storage. Thus green fruits can be stored for 18 days at 59°F., turning fruits for 16·4 days at 59°F. and ripe fruits for 12·6 days at 32°F. According to Cheema and Gandhi [1925] green sapotas can be stored for one month at 40-50°F. after which they will ripen normally on removal from cold storage. As a result of work done at Kirkee [1944], it was found that ripe fruit could be stored for six weeks at 32-35°F.

In the present investigation an attempt was made to determine the optimum cold storage conditions for sapotas grown in the Mysore State. Only fully grown and hard fruits were stored at the following temperature ranges.

(1) 35-38°F. (R.H. 85-90 per cent), (2) 42-45°F. (R.H. 85-90 per cent), (3) 47-50°F. (R.H. 85-90 per cent), (4) 52-55° F., (R.H. 85-90 per cent) and (5) Room temperature, 76-86°F. (R.H. 50-75 per cent).

Total soluble solids were determined by means of a refractometer. For the estimation of ascorbic acid, 10 gm. of sapota tissue was macerated in a blendor, using 100 c.c. of two per cent metaphosphoric acid and filtered. The filtrate was titrated against a standard solution of 2 : 6 dichlorophenol indophenol.

The physiological losses in weight in sapotas during storage were found to be the least at 35-38°F. There was an increase in the percentage of total soluble solids in sapotas at all the temperature ranges. There was first a decrease and then an increase in total acidity in the fruits stored at various temperatures. The ascorbic acid content decreased at all the temperature ranges. The optimum conditions for the cold storage of sapotas are a temperature of 35-38°F. and a R.H. of 85-90 pe cent. The approximate storage life is eight weeks and the post-storage life 3-5 days.

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REVIEWS

LAND REFORM

DEFECTS IN AGRARIAN STRUCTURES AS OBSTACLES TO ECONOMIC DEVELOPMENT

(*Published by the Department of Economic Affairs, United Nations, New York, 1951, pp. 101, Price $0·75*)

THIS report has been prepared by the United Nations Office in pursuance of the General Assembly's resolution which entrusted it with making "an analysis of the degree to which unsatisfactory forms of agrarian structure and, in particular, systems of land tenure in the under-developed countries and territories impede economic development and thus depress the standards of living especially of agricultural workers and tenants and of small and medium-sized farmers". With the aid of examples drawn from different under-developed countries, the report describes the main features of agrarian structures in these countries, reforms designed to improve the size of holdings and the conditions of tenure, and relations between the agrarian structures and economic development. In its last chapter is given a summary of the principal conclusions.

The evidence collected suggests the widespread occurrence of certain features throughout the under-developed countries of the world though their significance varies from area to area. Among the factors which have most serious effects on economic development are the uneconomic size of farms ; the maldistribution of land ownership with concentration of large estates insufficiently utilised and the landless press of a large part of the population ; the fragmentation of holdings the high rents and insecurity of tenure ; indebtedness and lack of credit facilities for the small farmer ; absence of settled title to land and water ; plantation economies which offer low wages and no share in management to the cultivators ; burdensome taxation policies ; and, in general, an unsatisfactory set of incentives for a rising and sustained agricultural production. In view of the variations in the relative importance of these factors from region to region, the programme of reforms have to be worked out carefully with reference to the requirements of each region. In Asia, for example, the outstanding features of the agrarian structure are the prevalence of large numbers of uneconomic holdings, fragmentation, high rents and a heavy burden of debt on the peasant cultivator. In parts of South America, while there is no dearth of cultivated and cultivable land, the concentration of large estates reduces a large part of the rural population to the status of labourers with very low living standards or to small cultivators with precarious conditions of tenancy. No concrete programme of reforms has thereof been proposed in the report, but only the directions in which it might be desirable to effect improvements have been indicated in a broad manner. The report gives many examples of several different types of reforms already being introduced, such as, the great change from the tenancy to ownership which is now in process in many countries of Asia ; the redistridution of estate lanb

to farm labourers in Mexico ; registration of title to land ; types of large-scale organization designed to give security of tenure to small farmers on a communal basis and the development of co-operative activities in the spheres of credit, marketing and production in European and other countries, etc.

The land reforms, though necessary for improving the cultivators' status and for creating suitable environments for further economic development, are by themselves not always sufficient. In countries, such as those in Asia, where the relationship between population and land is unfavourable and where the density of farm population is increasing, redistribution of land ownership alone will not remove one of the most serious defects of the agrarian structure, namely, the large number of excessively small farms, nor is it likely to offer land or fuller employment to most of the landless labourers. Side by side with the introduction of land reforms, it is necessary to work for greater intensification of agricultural production and greater diversification of employment through industrialization. Rightly the report lays stress on the fact that changes in the land tenure system are more likely to lead to a rise in the standard of living of the farmers and farm workers when they form part of a general programme for the improvement of agriculture than when they are undertaken in isolation. The importance of tackling agrarian problems on an integrated basis is, however, already fully recognized in this country and is well reflected in our Five-Year Plan.

The serious lack of data on the subject in under-developed countries, and shortage of time at the disposal of compilers rendered any exhaustive survey of agrarian structures of different countries difficult. The treatment is, therefore, selective and precise. Being limited in scope, the report does not attempt a comparative study of the different land systems or of the merits of different forms of agrarian structures. Nor does it discuss the practical methods by which changes can be most successfully carried out. Nevertheless, it is valuable as giving a general picture of the defects of the agrarian structures in the under-developed regions, the measures which are being taken to remove them and the lines along which improvements might be introduced. A knowledge of the experiences of other countries and regions in the matter of reform of their agrarian structures, can be a useful guide when evolving suitable measures of agrarian reforms in a particular area. A perusal of the report will certainly be useful to those interested in the subject of agrarian reforms. (M.S.M.)

MOBILISATION OF DOMESTIC CAPITAL IN CERTAIN COUNTRIES OF ASIA AND THE FAR EAST

(*Published by the Economic Commission for Asia and the Far East, 1952, pp. 239, Price $1·50*)

IN conjunction with other specialised agencies of the U. N. O., the Economic and Social Council and its regional commissions have in recent years brought out a number of studies bearing on the problem of the financing of economic development of under-developed countries. The report under review brought out by the E. C. A. F. E. Secretariat is an important addition to such studies and represents

an attempt on the part of the E. C. A. F. E. to examine the existing institutional arrangements for the mobilisation of domestic capital, to indicate gaps and to suggest lines of approach for promoting and channeling savings for productive employment.

The report opens with a description of the general economic, social and political background of the region in terms of which alone appraisals have to be made and remedies sought. While low levels of income, rapid growth of population and limited entrepreneurial talent are given as the main economic factors limiting rapid growth of savings, political insecurity and lack of confidence in the solvency of the Government and the stability of the local currencies are additional factors hampering savings at least in some countries of the region. The report emphasises the need for external financial assistance to break the vicious circle of lack of savings and lack of development.

A comprehensive review of the existing financial institutions which assist in the mobilization of capital, is given in the next three chapters dealing respectively with the central banks (Chapter II), the organised and unorganised money markets (Chapter III) and the capital market (Chapter IV). Among the suggestions made for improving conditions in the organised money market, the one relating to the need for enhancement of rates of interest in commercial bank deposits deserves special attention. The report reveals that in some countries, leading commercial banks actually refuse to pay any interest or pay less than on savings account and suggests that in order to discourage wasteful expenditure by individuals and even governments the rates of interest should be enhanced so as to offer greater incentives to the people to save a part of their income. The report, however, emphasises that this would be possible only if the banks can find profitable uses for the funds raised and suggests that a programme for increasing savings through the offer of higher rates should be integrated with expanded sales of government and other securities both to banks and, through them, to the general public. In regard to the sectors of economy served by the unorganised money market constituted by the moneylenders and other unregulated firms, the report has stressed the need for increasing the capacity for savings by expanding production. The problem here is, however, complicated by many factors including the costly burden of credit available for investment in this sector. For improving conditions in this regard, the report has suggested the regulation of the unorganised money market on the one hand and the extension of institutional credit, especially co-operative credit, on the other. Though the main suggestions for the strengthening of the co-operative system of credit are already being tried in this country, the one that certainly merits some attention of the State Governments and co-operative thinkers here relates to the extension of State guarantees of repayment in regard to deposit accounts in such societies as have already shown sound performance.

In regard to long term savings, the report stresses the importance of the extension of post office saving facilities and life insurance to rural areas. The report suggests that the governments of the region may examine the possibility of using post offices, co-operatives and some other government agencies for sale of insurance. In some

countries, the insurance law may have to be suitably revised for safeguarding the interests of the policy holders. The report also touches the subjects of long term-finance for agriculture and industrial development. For the agricultural sector the report mentions the generally accepted ideas of the strengthening of land mortgage banking and the establishment of state agricultural banks. For long term industrial finance, direct financing by government establishment of financing corporations and government guarantees for attracting private resources for investment are the usual methods used by the governments of the region.

The poverty of the region and the consequent low level of voluntary savings underlines the need for, and importance of, state action for mobilising financial resources through suitable fiscal measures. As the report was prepared at a time when inflationary pressures were very acutely felt, it suggests that the governments should look to internal financing of economic development only from (*a*) surplus of revenue over current expenditure, (*b*) non-bank loans, (*c*) profits from state enterprises and (*d*) where feasible, reduction of foreign securities. In regard to taxation, the report suggests that while there is not much scope for increase of taxes, increased tax revenues would be possible through improved tax collections.

The report ends with a review of experiences of a few countries of the region including India, Burma, Indonesia and Pakistan, which can be helpful to others.

The report is very well documented and would repay a close study by all those interested in the subject of the financing of economic development in under-developed countries. (M.S.M.)

PLANT DISEASES

By F. T. Brooks

(Published by Geoffery Cumberlege, Oxford University Press, London E. C. 4, 1953, pp. 457 and 62 text-figures, Price 38s)

THE first edition published in 1928 was reviewed in detail and the rapid development in the subject since that date is reflected in considerable change in the contents in the new edition. The author has tried to provide under one cover a concise and selfcontained account of important plant diseases of British crop plants and the Commonwealth. The book is divided into XXII chapters, and two of these are devoted to the introduction of non-parasitic and virus diseases in an elementary fashion. In a book of this type one cannot expect that these subjects can be dealt with adequately, as in view of recent work a separate book is required to deal with these. In chapters V to XX the author has given a lucid and concise account of the important fungal plant diseases and has provided additional illustrations. Although the author has adopted in general the latest nomenclature, the classification followed is that of 'Gwynne Vaughan and Barnes'. It would have been more desirable to follow Martin's classification.

The genus *Urophlyctis* has been retained whereas it is considered a synonym of *Physoderma*. *Sclerospora graminicola* has been stated to attack *Penninsetum typhoides* and *Sorghum vulgare* implying that different physiologic races of the fungus

are responsible for the two diseases, but the present state of our knowledge is that two different species are involved. Accounts of the genera *Sphacelotheca* and *Tolyposporium* and *Fungi imperfecti* as a group are too meagre, although they are responsible for many important diseases. Under *Uromyces fabae* it would have been desirable to record that the disease is perpetuated through telia in India.

This revised edition of the book would be very welcome to students and research workers alike. (R.S.V.)

ECONOMIC SURVEY OF ASIA AND THE FAR EAST, 1952

(Published by the United Nations, New York, 1953, pp. 104, Price $ 1·0)

THE Economic Survey of Asia and the Far East, 1952, is the sixth in a series of annual reports prepared by the Economic Commission for Asia and the Far East. This Survey, while following more or less the same pattern of treatment as in earlier reports, deals mainly with the developments during the first half of the year. This Survey has also been issued as Volume 3, No. 3, of the Economic Bulletin for Asia and the Far East.

The Survey is divided into three parts, the first part dealing with agricultural, mineral and industrial production, the second part dealing with international trade and payments and the third part dealing with monetary and fiscal developments. A number of tables and charts have also been given to explain and substantiate the various facts mentioned in the Report.

In the production sector, the Survey gives an evidence of a general, though uneven, improvement in the E.C.A.F.E. region in the year 1952 compared to that during the previous year. This improvement, it is contended, is likely to continue in view of the higher prices of foodstuffs, intensified development in the field of food production, inflow of foreign aid funds and technical assistance, etc.

So far as trade is concerned, however, the Survey gives an evidence of certain depressive influences which resulted in a decline in the demand for the principal export commodities and the consequent drop in export prices. The main factors responsible for this situation were firstly, the collapse of raw material boom of 1950-51 resulting from Korean war, and secondly, the world recession in textile. While the prices of exportable goods, particularly raw material declined, those of imported goods particularly of food went up ; this affected adversely the terms of trade and consequently the balance of payment position of all but the rice surplus countries.

The prices in the region generally showed a downward trend as a result of increased supplies, liquidation of commodity stocks, monetary policy, etc. As regards financial aspects, two special developments were the loss in revenues on account of collapse in the export boom and the decline in foreign exchange reserves. The financing of imports became a serious problem.

The Survey arrives at certain important conclusions. These are (*a*) that the factors which brought decline in exports are likely to have a certain degree of permanency ; (*b*) that the factors on the supply side have become a potent influence and

the output can adjust itself to moderate increases in demand without the stimulus of higher prices; and (c) that the import requirements of the developing countries are growing and they are likely to press heavily against the availability of foreign exchange.

On the whole, the E.C.A.F.E.'s Secretariat have gone deep into the problem facing the region in question and have made a dispassionate study thereto. The Survey is really an useful document and the conclusions arrived at therein can benefit the countries of the region in working out their programmes and policies. (R.N.P.)

FARM MECHANIZATION HAND BOOK

By T. Hammond Cradock

(Published by Temple Press Ltd., London, 1952, pp. 332, Price 10s. 6d.)

THIS is the second edition of the book first published in 1948. This edition which is re-written, is useful to the mechanic or engineer who is entrusted with the maintenance, operation and repair of agricultural tractors, ploughs, combines, balers, mowing machines, etc. There is also a small description of the equipment needed for a small repair shop.

The book deals with tractors and agricultural machines built in England and details of hydraulic lifts, etc., of the more common British tractors are given. Mention about other agricultural machines such as combines, mowers, haybalers, etc., is made but this is of less importance to countries like India, where such machines have not found such economic use. The instructions in the book are for the man on the job, who is confronted with practical field work and maintenance of machines. At the end of the book, there is a useful appendix, giving data of tractors and engines produced in the U. K. for agricultural purposes. The specifications and illustrations of the tractors and engines are to be found in this part.

The book is of practical value to engineering firms, which undertake repair of tractors, automobiles, engines and other agricultural machines. (R.V.R.)

FARM ENGINES AND TRACTORS

By Harold E. Gulving

(Published by McGraw Hill Book Co. Inc., New York, 1953, pp. 397, Price $ 6·0)

THIS book is written for students taking degree courses in agricultural and agricultural engineering, in American Universities. The contents are based on elementary principles and as such a previous knowledge of physics and mathematics is not assumed. Students of the matriculation standard in India, can be introduced to this book with least difficulty. The book will be of interest to farmers, who own and operate tractors or engines on their farms. This book will be useful in India, to students taking engineering courses in technical schools of a diploma standard.

The book deals with the principles of engine operation, describes the functions of different parts and units in an engine, and gives hints on good engine maintenance. There is also a chapter on diesel engines, as a small percentage of engines used on farms in the U. S. A. is run on diesel fuel. 'The most interesting chapter in this book is chapter 16 which deals with selecting a tractor or engine'. It gives a history of the progress of tractors and describes the significance of the ' Nebraska Tractor Tests'. It explains in simple language, what each one of the 'Nebraska Tests' means and finally the author indicates the points for consideration in interpreting the 'Nebraska Test' for selecting a tractor. This part where the results of the ' Nebraska Test ' are interpreted, is a contribution to the technical study for selection of tractors and engines and deserves a study by Agricultural as well as Mechanical Engineers. Chapter 17 deals with ' tune up ' and hints for good maintenance. Here he describes certain practical tests and checking procedure that an engine owner can attend to without the assistance of a dealer. The last chapter deals with tractor operation and describes procedures for checking engine or tractor before starting the same. There are review questions at the end of each chapter ; these are useful in teaching for the diploma standard in our technical schools.

The chapter on ' selecting a tractor or engine ' is particularly recommended for engineers and research workers. (R.V.R.)

PRINCIPLES OF CROP HUSBANDRY IN INDIA

By A. K. Yegna Narayan Aiyer

(Published by the Bangalore Press, Bangalore, 1953, pp. XXVIII and 550, Price Rs. 17-8)

THE first edition of the book was brought out in 1948 and was hailed as a distinct contribution to the then available literature on Indian agriculture. The mere fact that a second edition of the book has been called for testifies to its usefulness to those who happen to be interested in crop husbandry in India.

The book in its scope covers all the different phases of agriculture with particular reference to Indian conditions. All the factors that affect crop production have been dealt with ; even the financial and marketing aspects of crop raising have not been left out. There are altogether twenty-five chapters and three appendices of which the first two are particularly useful. Beginning appropriately with climatic factors in relation to Indian agriculture, the text deals successively with soils, different aspects of soil management, manures and fertilizers, seeds and sowing, rotation, pests and diseases, improved varieties, implements, tractors, storage, etc. to mention some of the subjects treated in different chapters. Chapter XXIV contains helpful hints on the selection of farms, while the last chapter deals with the business side of crop production. Appendices I and II will be specially appreciated ; in the former are given the botanical names of the plants mentioned in the text and in the latter are listed some useful publications in the field of agriculture.

While the book may possibly be used as a text-book in graduate and undergraduate classes, the treatment is such as can be easily comprehensible to the general reader without any specialised knowledge of basic sciences relating to agriculture. For this reason it will have a wider appeal than a text-book prepared only for formal courses. The author has had many years experience in the field of agriculture both as a technical officer and as an administrator and has left the impress of his wide experience in the planning and writing of the book. It is an attractive, neatly printed publication ; the binding and get-up are also satisfactory. (U.N.C.)

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Reference to literature arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets, when the author's name occurs in the text, the year of publication only need be given in brackets. If the reference is made to several articles published by one author in a single year these should be numbered in sequence and the number quoted after year both in the text and the collected references.

If a paper has not been seen in original it is safe to state original not seen. Sources of information should be specifically acknowledged.

As the *format* of the journal has been standardized the size adopted being crown-quarto (about 7½ in. × 9⅝ in. cut) no text-figure, when printed should exceed 4½ in. × 5 in. Figures for plates should be so planned as to fill a crown-quarto page, the maximum space available for figures being 5¼ in. × 8 in. exclusive of that for letter press printing.

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